



PAKISTAN
CHEST SOCIETY
STRIVING FOR PULMONARY CARE

Clinical Practice Guidelines

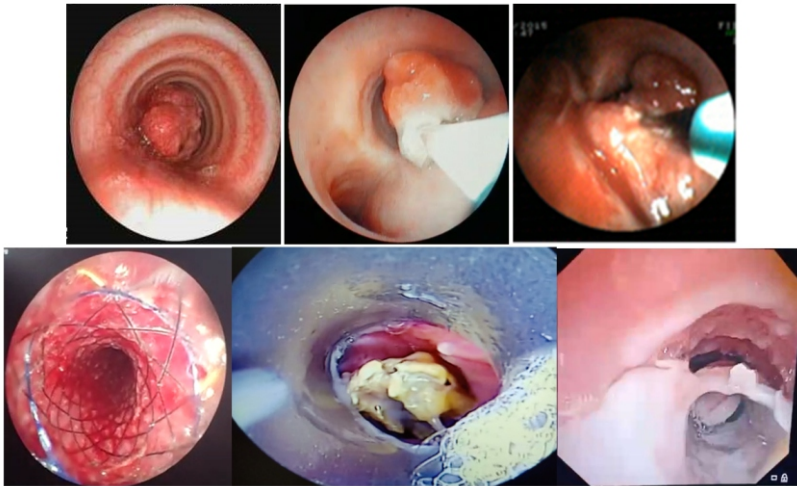
Rigid Bronchoscopy

PAKISTAN CHEST SOCIETY-2026

Rigid Bronchoscopy Guidelines

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First Edition May 2026
Pakistan Chest Society



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CHEST SOCIETY**
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Preface

It is with immense pleasure that I introduce the first edition of the Pakistan Chest Society guidelines on rigid bronchoscopy. As we embark on this journey, we recognize the pivotal role this procedure plays in diagnosing and managing complex airway diseases. Interventional pulmonology is gaining momentum in Pakistan, mirroring global trends, with a growing number of centers and young pulmonary physicians eager to master techniques like rigid bronchoscopy. Rigid bronchoscopy is a powerful tool that enables pulmonologists to intervene effectively in conditions that were once considered challenging, offering new hope to patients with airway stenosis, tumors, and other thoracic pathologies.



These guidelines have been crafted with meticulous attention to detail, incorporating international best practices and tailored to meet the unique needs of our healthcare landscape in Pakistan. They cover essential aspects of rigid bronchoscopy, including patient selection, procedural techniques, and perioperative care, aiming to standardize the practice and enhance patient outcomes.

I extend my deepest gratitude to the dedicated members of the guideline committee, whose expertise and relentless efforts have made this document a reality. I also acknowledge the invaluable contributions of our patients, whose cases have enriched our understanding, and our mentors, who have inspired us to strive for excellence.

To all healthcare professionals, I hope these guidelines serve as a comprehensive resource, empowering you to advance your skills in rigid bronchoscopy and elevate the standard of respiratory care in Pakistan. Let us continue to learn, innovate, and push the boundaries of what is possible in thoracic medicine.

Thank you.

Prof. Dr. Talha Mahmud

Chairman
Rigid Bronchoscopy,
Guidelines Development Committee

Message by the President Pakistan Chest Society

It gives me immense pleasure to present the Guidelines on Rigid Bronchoscopy- First Edition 2026, published by the Pakistan Chest Society. Rigid bronchoscopy continues to be an indispensable tool in both the diagnosis and management of complex airway disorders, foreign body aspiration, and acute airway emergencies. Despite advances in flexible bronchoscopy and interventional pulmonology, the role of rigid bronchoscopy remains central due to its ability to provide a secure airway, superior suction, and the capacity to manage bleeding and large lesions effectively.



These guidelines represent a commendable and much-needed effort to standardize clinical practice, enhance procedural safety, and promote evidence-based respiratory care across Pakistan. By consolidating current best practices and expert consensus, they will help reduce variability in technique, improve patient outcomes, and provide a clear framework for training the next generation of pulmonary specialists.

I sincerely appreciate the dedication, expertise, and collaborative effort of all contributors, reviewers, and experts who worked tirelessly to bring this document to fruition. Their commitment reflects the highest standards of academic rigor and clinical responsibility. I am confident that these guidelines will serve as an invaluable resource for pulmonologists, thoracic surgeons, ENT surgeons, anesthesiologists, and trainees alike. I congratulate the guideline committee on this significant academic achievement and hope that this initiative will further strengthen bronchoscopy services, teaching, and research throughout the country.

Prof. Shereen Khan

President
Pakistan Chest Society

Message by the Chairman Guideline Committee, Pakistan Chest Society

It gives me great pleasure to present the 1st Edition of Guidelines for Rigid Bronchoscopy, developed under the auspices of the Pakistan Chest Society.

Rigid bronchoscopy remains a cornerstone intervention in the diagnosis and management of complex airway disorders, offering rapid restoration of airway patency and enabling therapeutic procedures such as tumor debulking, balloon dilatation, and stent placement. In our setting, where malignant airway obstruction, post-intubation



stenosis, and tracheobronchial tuberculosis are frequently encountered, standardized, evidence-based guidance is both timely and critical. These guidelines have been meticulously developed to integrate international best practices with the clinical realities and resource constraints of healthcare delivery in Pakistan, with a strong emphasis on patient safety, procedural competency, and multidisciplinary decision-making.

I would like to extend my sincere appreciation to the dedicated working group for Rigid Bronchoscopy first PCS guidelines, under the able chairmanship of Prof. Talha Mahmud, for their scholarly contributions, commitment, and expertise in producing this comprehensive document. It is our hope that these guidelines will serve as a practical resource for pulmonologists, thoracic and ENT surgeons, and anesthesiologists, strengthen procedural proficiency, and ultimately improve outcomes for patients with central airway disease across the country.

With best wishes,

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Acknowledgement

We extend our heartfelt gratitude to the distinguished members of the Pakistan Chest Society (PCS) Rigid Bronchoscopy Guidelines Committee for their expertise, dedication, and meticulous work in developing these guidelines. Their collective contributions have been instrumental in shaping this comprehensive and clinically relevant resource. We also wish to acknowledge the unwavering support and encouragement of our families, whose patience and understanding have been a constant source of motivation throughout this project.

Our sincere appreciation goes to the dedicated team at Shaikh Zayed Hospital, including trainee doctors, staff nurses, and allied health staff. Their tireless commitment to patient care and their active role in the clinical and academic environment made this work possible. Special thanks are due to the anesthesia team for their critical role in conducting rigid bronchoscopy procedures. Their expertise in managing the shared airway and maintaining patient safety under challenging conditions is fundamental to the success of every intervention.

Finally, we express our deepest gratitude to our patients. Their trust in our care and their generous consent for the use of clinical images for educational purposes have been invaluable in advancing medical knowledge and improving outcomes for future patients.

Dedication

To those who breathe with difficulty, yet persevere,

In the narrow passages of the airway, we see the breadth of human resilience. Your struggles, though unique, resonate with the universal longing for unobstructed breath, for the simple freedom to inhale and exhale without constraint. These guidelines are a tribute to your courage, a testament to our commitment to advancing the art of airway care.

They embody the precision of science, the compassion of caregivers, and the unwavering dedication to easing the burden of those who face the challenges of complex airway disease. We dedicate this work to you, not merely as patients, but as individuals whose lives remind us of the profound gift of breath.

May these guidelines illuminate the path to innovative treatments, more effective interventions, and the restoration of breath as a source of life and joy. May they remind you that in the journey of airway health, you are seen, you are heard, and you are not alone.

In the words of a poet, "What is life without breath?" We answer, it is a life unfulfilled. It is with the breath of hope, compassion, and innovation that we dedicate these guidelines to you, striving for a future where every breath is a testament to possibility.

For every breath taken, for every life touched, we are here.

List of Abbreviations

ABG	Arterial Blood Gas
AI	Artificial Intelligence
APC	Argon Plasma Coagulation
ASA	American Society of Anesthesiologists
BP	Blood Pressure
CAO	Central Airway Obstruction
CRE	Controlled Radial Expansion
CXR	Chest X-ray
DOAC	Direct Oral Anticoagulants
EBUS	Endobronchial Ultrasound
ENB	Electromagnetic Navigation Bronchoscopy
ENT	Ear Nose Throat
ETT	Endotracheal Tube
FB	Foreign body
Hb	Hemoglobin
HDU	High Dependency Unit
ICU	Intensive Care Unit
IV	Intravenous
LMB	Left Main Bronchus
NPO	Nil Per Oral
PSI	Pounds Per Square Inch
SEMS	Self Expanding Metallic Stents
SpO2	Saturation of Oxygen on Pulse Oximeter
TIVA	Total Intravenous Anesthesia
TB	Tuberculosis
QoL	Quality of Life

Introduction

Interventional pulmonology's tale is one of trailblazers, innovation, and perseverance, fueled by technological advancements and unwavering passion, unfolding alongside the progress of the last century. Bronchoscopy's origins date back to 1897 when Gustav Killian (father of bronchoscopy), a German rhinolaryngology head, used a rigid esophagoscope to remove a pork bone from the right main bronchus of a farmer, marking the birth of bronchoscopy. The first paper on direct bronchoscopy followed in 1898.¹ Meanwhile, in the USA, Chevalier Jackson (father of American bronchoesophagology) was revolutionizing rigid bronchoscopy. He introduced an endoscope with a distal light in 1904 and pioneered endobronchial treatments for tuberculosis (TB) complications, including the first reported endoluminal resections of endobronchial tumors.² The 1960s marked a groundbreaking era in bronchoscopy with the introduction of the flexible bronchoscope allowing procedures without general anesthesia. Shigeto Ikeda, a thoracic surgeon at Tokyo's National Cancer Center, pioneered this innovation in 1966, enabling exploration of peripheral bronchi, simplifying the procedure, and improving patient comfort.³ The introduction of flexible fiberoptic bronchoscopes in 1968 led to a decline in rigid bronchoscope usage. The flexible bronchoscope's popularity grew post-1968 due to its minimally invasive nature, lack of need for general anesthesia, and better peripheral airway visualization. As a result, rigid bronchoscopy use declined over the next two decades, becoming rare and almost obsolete, except among a few dedicated physicians, mainly in Europe.⁴ Jean-Francois Dumon, a French pulmonologist, revived interest in rigid bronchoscopy in the 1980s with his work on laser vaporization, photocoagulation, and silicone stenting. His development of the Dumon silicone stent was a game-changer, popularizing airway stenting and sparking a global resurgence of rigid bronchoscopic procedures. Although stent deployment dates back to 1915, major advancements came with the Montgomery T tube (1960s) and Dumon's silicone stent (mid-1980s). The first airway stent was placed in Marseille in 1985, making stenting a key part of managing airway compromise in benign and malignant conditions, and re-establishing rigid bronchoscopy's importance in interventional pulmonology.^{4,5}

Rigid bronchoscopy is a specialized endoscopic technique utilizing a rigid scope to provide direct visualization and intervention in the central airways (trachea and main bronchi). It has regained its crucial role in interventional pulmonology, providing options for both surgical and non-surgical patients. Rigid bronchoscopy in majority of cases is performed alongside flexible bronchoscopy, but it can also be used as a standalone diagnostic procedure. Unlike flexible bronchoscopy, the rigid instrument's larger working channel enables the use of larger instruments, facilitating complex procedures like foreign body (FB) retrieval, tumor debulking, stent deployment, and managing severe hemoptysis. Although requiring general anesthesia and expertise, rigid bronchoscopy offers superior airway control, addressing complex pathologies that may be very challenging with flexible bronchoscopy.^{5,6} It's a crucial tool for interventional pulmonologists, playing a central role in managing complex airway disorders - both cancerous and non-cancerous. It provides controlled access to the airway, enabling various treatments like laser therapy, cryotherapy, electrocautery, argon plasma coagulation (APC), and photodynamic therapy, among others.⁴

In Pakistan, rigid bronchoscopy's often handled by ENT surgeons, typically in operation theatres under general anesthesia, mainly for retrieving FBs from the larynx and trachea.⁷ Pakistan is witnessing a surge in interventional pulmonology. Interestingly, a review on Rigid Bronchoscopy by a French author was published in the Pakistan Journal of Chest Medicine (Vol 18, No 1, 2012).⁸ Fast forward to 2021, a Pakistani interventional pulmonologist presented "Revival of Rigid Bronchoscopy" at PCS Chestcon, Karachi, highlighting the growing expertise in this field.⁹ As techniques and technology evolve, rigid bronchoscopy's role in managing airway disorders will keep growing. Despite varying applications globally, Pakistan Chest Society's initiative to create first National guidelines for the junior and senior pulmonologists with interest in airway interventions is timely. Recognizing the procedure's evolution, current status, and future directions will help establish a framework for safe and effective use, ultimately boosting patient care.

Anatomy, Physiology, and Pathophysiology of the Central Airways

The central airways form the anatomical and functional conduit between the upper respiratory tract and the distal bronchial tree. In interventional pulmonology, detailed knowledge of central airway anatomy, physiology, and pathological alterations is fundamental for diagnostic bronchoscopy, therapeutic bronchoscopy, airway stenting, tumor debulking, and management of airway obstruction.^{10,11,12} Central airway diseases significantly contribute to morbidity and mortality due to impaired ventilation, secretion retention, recurrent infections, and respiratory failure. Modern interventional pulmonology relies heavily on understanding both normal airway structure and the pathophysiological mechanisms underlying airway compromise.

The central airways typically refer to the trachea, mainstem bronchi, bronchus intermedius, and lobar bronchi. These structures keep the airways open and support gas exchange, mucociliary clearance, and host defense. Pathologies involving the central airways can be neoplastic, inflammatory, infectious, traumatic, or congenital in origin.^{10,11} Interventional pulmonologists frequently encounter airway stenosis, tracheo-bronchomalacia, tumors, fistulas, and post-intubation injuries.¹³

Anatomy of Central Airways **Larynx and Subglottic Region**

A detailed understanding of laryngeal anatomy is essential for safe and effective rigid bronchoscopy. The rigid bronchoscope passes through the oral cavity, pharynx, and larynx before entering the trachea. The larynx represents the narrowest and most vulnerable portion of the upper airway encountered during instrumentation. Knowledge of its anatomical landmarks, dimensions, cartilaginous framework, musculature, innervation, and functional dynamics is critical for minimizing trauma, ensuring adequate ventilation, and successfully performing therapeutic interventions.¹²

Rigid bronchoscopy requires alignment of the oral, pharyngeal, and laryngeal axes under general anesthesia. During insertion, the bronchoscope traverses the supraglottic structures and passes through the vocal cords into the subglottic space. Consequently, interventional pulmonologists must understand the anatomical relationships relevant to airway access, endoscopic orientation, and potential complications. Grossly divided into **supraglottic, glottic and subglottic regions.**

Supraglottic Anatomy: Epiglottis is a leaf-shaped elastic cartilage attached inferiorly to the thyroid cartilage and hyoid bone. During rigid bronchoscopy, the bronchoscope blade elevates the epiglottis anteriorly, exposing the glottic opening. If elevation is inadequate, visualization of the glottis may be obstructed.

Aryepiglottic Folds extend from the lateral margins of the epiglottis to the arytenoid cartilages and form the lateral boundaries of the laryngeal inlet. They contain cuneiform and corniculate cartilages. Edema or tumor infiltration in this region can significantly complicate rigid bronchoscope insertion.

False Vocal Cords lie inferior to the aryepiglottic folds and superior to the true vocal cords. They are covered by respiratory epithelium and play a minor role in phonation. During bronchoscopy they serve as important landmarks for identifying the true glottic opening.

Glottic Anatomy

True vocal cords are the most critical anatomical structure encountered during rigid bronchoscopy. They are composed of stratified squamous epithelium covering the vocal ligament and vocalis muscle, and appear as pearly white structures anchored anteriorly to the thyroid cartilage and posteriorly to the arytenoid cartilages. The opening between them is called the rima glottidis, which represents the narrowest point of the adult laryngeal airway during phonation. Passing the rigid bronchoscope through the vocal cords requires adequate neuromuscular relaxation, proper alignment of the airway, and gentle rotational movements to avoid trauma to the cords.

Arytenoid Cartilages paired pyramidal cartilages situated on the posterior cricoid lamina. During rigid bronchoscopy excessive posterior pressure can dislocate or even cut arytenoid cartilages and prolonged instrumentation may produce mucosal ulceration.¹³

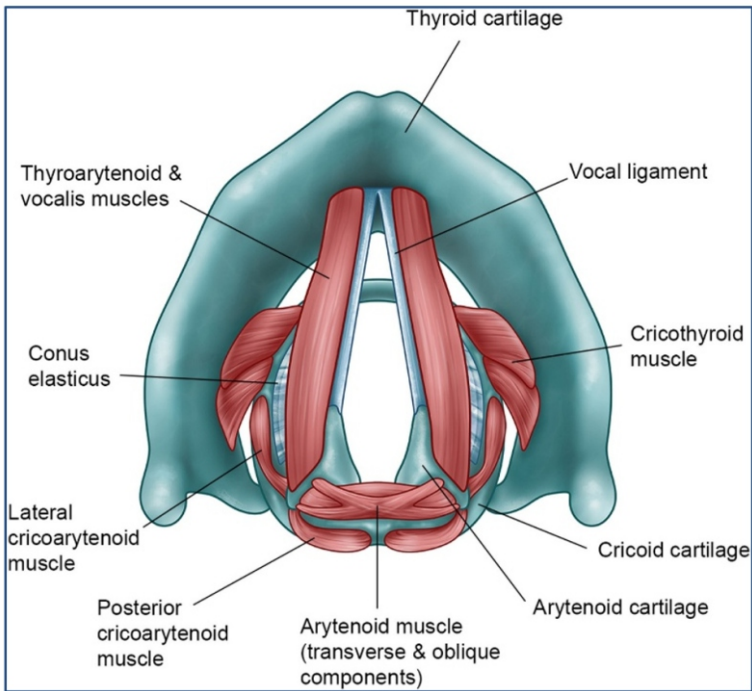


Figure 1. Anatomy of the larynx.

(Source: <https://teachmeanatomy.info/neck/viscera/larynx/>)

Subglottic Anatomy

The sub-glottis extends from inferior border of the vocal cords to the lower border of the cricoid cartilage. This region is clinically important because it is:

- The narrowest fixed portion of the adult airway.
- Highly susceptible to stenosis.
- Frequently injured during prolonged intubation.

The mucosa is tightly adherent to the cricoid cartilage, making it vulnerable to ischemic injury from pressure. Larynx is innervated by Vagus nerve through superior laryngeal nerve and recurrent laryngeal nerve provides motor supply to all intrinsic muscles except cricothyroid.

Blood supply is derived from superior laryngeal artery and inferior laryngeal artery. These vessels may bleed during tumor biopsy, laser therapy or mechanical trauma.

Trachea

The trachea is a flexible, fibrocartilaginous tube that serves as the main conduit for air between the larynx and the bronchi. It begins inferiorly at the cricoid cartilage, corresponding to the level of the sixth cervical vertebra (C6), and extends downward through the neck and upper thorax. The trachea terminates at the carina, where it bifurcates into the right and left main bronchi, typically at the level of the fifth thoracic vertebra (T5). Anteriorly, its lower portion lies just behind the manubrium sterni. In adults, the trachea measures approximately **10–13 cm** in length and **2–2.5 cm** in diameter with approximately **16–20 C-shaped cartilaginous** tracheal rings. These cartilages are made of hyaline cartilage and support the tracheal structure and patency.¹⁴ The posterior membranous wall lacks cartilage and is composed mainly of the trachealis muscle, which allows dynamic variation in tracheal diameter during coughing and forced expiration. The tracheal wall consists of four main layers:

Mucosa: Lined by pseudostratified ciliated columnar epithelium containing goblet cells, with a rich vascular and lymphatic network beneath.

Submucosa: Contains seromucous glands that produce secretions and contribute to airway humidification.

Cartilaginous layer: Composed of hyaline cartilage rings that provide structural support.

Adventitia: A connective tissue layer that anchors the trachea to surrounding mediastinal structures.

Carina and Main Bronchi

The carina is the bifurcation point of the trachea into the right and left main bronchi. It is highly sensitive and richly innervated, making it a major trigger point for cough reflex during bronchoscopy. Carinal anatomy is critically important in interventional pulmonology because malignant involvement, stenosis, or fistula formation at this site often requires advanced therapeutic interventions such as Y-stenting or rigid bronchoscopy. It's ideal place for Trans-bronchial Needle Aspiration (TBNA) or endobronchial ultrasound guided needle aspiration.

Right Main Bronchus is shorter, wider, and more vertically oriented than the left, measuring about 2–2.5 cm in length. This anatomy makes it more prone to aspiration of foreign bodies. It divides into bronchi supplying the right upper lobe, bronchus intermedius, right middle lobe, and right lower lobe, giving rise to 10 segmental bronchi in total.

Left Main Bronchus is longer and narrower, measuring approximately 4–5 cm, and runs beneath the aortic arch in close relation to cardiac structures. Its more acute angle and longer course make instrumentation slightly more challenging during bronchoscopy, particularly with a rigid bronchoscope.¹⁴

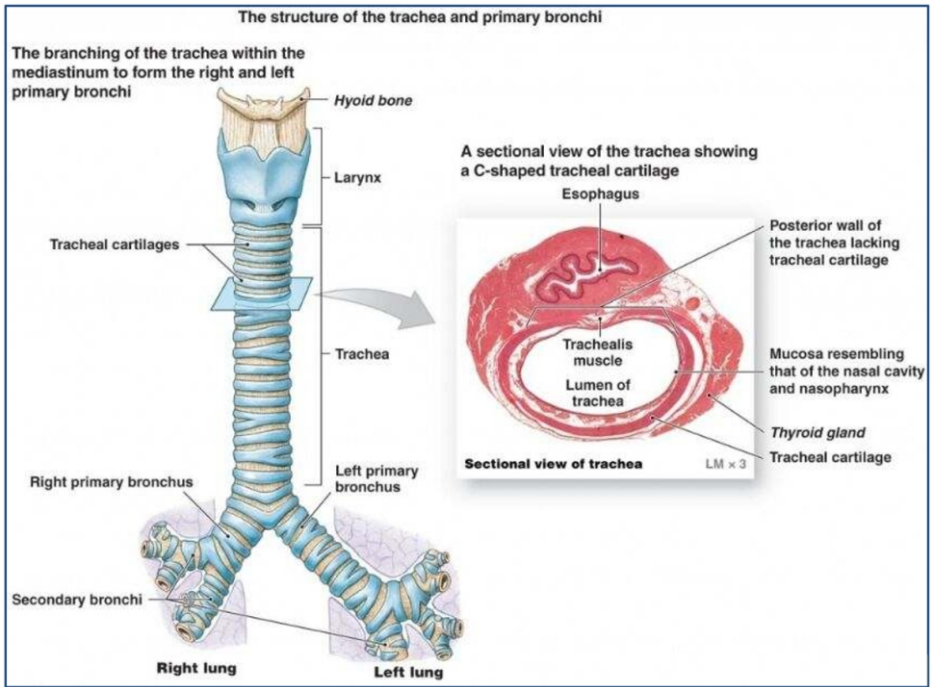


Figure 2. Anatomy of the trachea and bronchi.

(Source: https://healthiack.com/encyclopedia/trachea-diagram#google_vignette)

Blood Supply

The trachea is supplied by segmental arteries that differ between its cervical and thoracic portions.

Cervical trachea receives branches from the inferior thyroid arteries, which arise from the thyrocervical trunk of the subclavian artery. These branches run along the lateral aspects of the trachea and anastomose with each other to form a longitudinal vascular network along the tracheal wall.

Thoracic trachea supplied by tracheal branches of the bronchial arteries, which originate from the thoracic aorta or intercostal arteries. These branches also form an anastomotic network along the trachea, ensuring continuous perfusion.

Venous drainage occurs through brachiocephalic trunk for cervical trachea and bronchial veins into the azygos and hemiazygos veins for thoracic trachea.¹⁴ Understanding vascular anatomy is essential during therapeutic bronchoscopy because procedures such as tumor debulking, laser therapy, and cryotherapy carry bleeding risks.

Innervation

Airway innervation is derived from two main sources:

Parasympathetic fibers via the vagus nerve, which cause bronchoconstriction and increase mucus secretion.

Sympathetic fibers from the thoracic ganglia, which produce bronchodilation and reduce glandular secretion.

Sensory innervation mediates cough reflexes and other airway protective mechanisms.

Physiology of the Central Airways

Air Conduction

The primary physiological role of the central airways is conduction of air between the atmosphere and alveoli. The large diameter and cartilaginous support minimize airflow resistance under normal conditions.

Airflow resistance is governed by Poiseuille's law: $R \propto \frac{1}{r^4}$

Even minor reductions in airway radius can dramatically increase airflow resistance, explaining why central airway stenosis produces severe dyspnea.¹⁵

Mucociliary Clearance: The mucociliary escalator is one of the airway's key defense mechanisms and relies on ciliated epithelial cells, goblet cells, and submucosal glands. The cilia beat in a coordinated manner to move mucus and trapped particles upward toward the pharynx, where they can be swallowed or expectorated. Interventional procedures can temporarily impair mucociliary function through mechanical trauma or thermal injury.

Airway Defense Mechanisms

The central airways protect the lower respiratory tract through mechanical filtration, the cough reflex, air humidification, and immune surveillance. Alveolar macrophages, dendritic cells, and lymphoid tissue further contribute to this immune defense

Dynamic Airway Mechanics

Airway caliber changes during the respiratory cycle:

- Inspiration produces airway expansion through negative intrathoracic pressure
- Expiration may narrow airways due to increased pleural pressure

Cartilage provides rigidity while the posterior membranous wall allows flexibility. This dynamic behavior becomes clinically important in disorders such as tracheobronchomalacia.

Pathophysiology of Central Airway Disorders

Central Airway Obstruction

Central airway obstruction is a major indication for interventional bronchoscopy. Symptoms generally occur when the airway lumen is reduced by more than 50%.^{15,16,17,18}

Table 1. Causes of central airway obstruction.

Malignant Causes	Benign Causes
Primary lung cancer	Post-intubation stenosis
Thyroid malignancy	Tracheostomy-related injury
Metastatic tumors	Granulomatous disease
Esophageal carcinoma	Relapsing polychondritis
Thyroid malignancy	Amyloidosis
	Foreign body aspiration

Mechanisms of Obstruction

Airway obstruction may result from:

1. Intraluminal lesions: Stenosis, polyp, lipoma, tumor.
2. Extrinsic compression: Mediastinal tumor, goiter, aneurysm.
3. Mixed lesions: Mediastinal tumors invading wall to tracheal lumen.
4. Dynamic collapse: Tracheomalacia.

In tracheobronchomalacia, weakened cartilage causes excessive collapse of the airway during expiration. This excessive dynamic airway collapse is marked by a $\geq 50\%$ reduction in the airway lumen, air trapping, an ineffective cough, and recurrent respiratory infections.¹⁹

Tracheal Stenosis

Tracheal stenosis commonly develops after prolonged intubation or tracheostomy but shorter duration < 24 hours can lead to stenosis formation especially after upsized ETT or high balloon pressure causing ischemic necrosis. Ischemic injury from cuff pressure leads to mucosal ulceration, chondritis, fibrosis and healing with scar formation.^{17,18} Interventional techniques such as laser therapy, argon plasma coagulation, cryotherapy, and stent placement can provide rapid symptomatic relief.

Tracheoesophageal Fistula (TEF)

A tracheoesophageal fistula represents abnormal communication between the airway and esophagus, mostly caused by esophageal cancer, prolonged intubation, radiation injury, surgical complications. TEF can lead to aspiration, severe pneumonia, malnutrition and respiratory failure. Airway and esophageal stenting are important palliative interventions.

Anesthesia and Pre-op Management of Rigid Bronchoscopy

Airway and Respiratory Evaluation

Unlike flexible bronchoscopy, the rigid scope introduces unique anesthetic challenges because it occupies the airway, interferes with conventional ventilation, and is often used in patients with significant respiratory compromise.²⁰ Successful outcomes require careful planning, multidisciplinary communication between the proceduralist and anesthesiologist, and mastery of specialized ventilation strategies.²¹

Patients requiring rigid bronchoscopy often have significant central airway compromise which disturbs ventilation.^{20,21} Patients may have central airway obstruction due to tumor, foreign body, blood clots, or benign stenosis of the airway. Often, these obstructions are in the trachea, right main stem or left main stem bronchus.²² This can translate to patients effectively ventilating approximately 50% or less of their total lung capacity.

The most important things to assess pre-procedure is the baseline oxygenation, ventilatory status, location and severity of the obstruction based on CT-imaging, and mouth opening of the patient.^{23,24} Complication rates are seen to increase when there is an emergent need of the procedure, patient has an ASA status of 4 or greater, or baseline hypoxemia.^{25,26}

Baseline Oxygenation and Ventilatory Status

Baseline oxygen requirements are likely the single most important factor to assess tolerance of the procedure from the anesthesiologist point of view.²⁶ If the patient has no supplemental oxygen requirements, and is maintaining saturations above 95%, then their anesthesiologist risk would overall be low.²⁴ If the patient is requiring 2-5 liters/min of supplemental oxygen, then they would have a moderate chance of desaturations during the procedure. If the patient is on high oxygen requirements > 6 L/min, then they would likely be at a high chance of desaturation during the procedure.²⁴

However, it is important to note that with the procedural intervention, the goal is to relieve the ventilatory obstruction. Once the obstruction is relieved, then the ventilation and oxygenation should normalize quickly. Therefore, this should be discussed with the proceduralist to assess the expected procedural duration for the obstruction to be resolved. If there is benign tracheal stenosis, a single balloon dilatation may open the trachea sufficiently to improve all the ventilatory parameters within 2 to 5 minutes. However, a large airway tumor may take up to 60 minutes to remove, with additional risk of bleeding and temporary worsening of the ventilatory parameters.²⁵

Location of the Obstruction

The proceduralist and anesthesiologist should review the CT chest of the patient and assess the location of the central airway obstruction along with the underlying lung parenchyma. Assessing the location of the obstruction is crucial in deciding how to ventilate the patient in the procedure and the risk associated with it. If the central trachea is more than 80% occluded, then ventilation would be extremely challenging and chances of intra-procedural desaturations are high.²⁷

However, if that same lesion is obstructing less than 50% of the trachea, then the ventilation would be relatively easier. If there is a distal right bronchus intermedius lesion or a small FB

that needs to be extracted, then ventilation would be generally easy. If the location is in the proximal trachea, then there would be limited space to position a ventilatory tube. However, if the lesion is in the right bronchus intermedius, then a rigid tube or endotracheal tube can be easily placed to ventilate the patient.

The proceduralist should also review the lung parenchyma. If the lesion is unilateral, and the contralateral side of the lung is healthy, then it would be easier to ventilate the patient. However, if the contralateral side also has parenchymal changes such as emphysema or chronic fibrotic changes, then it would be much harder to ventilate or oxygenate the patient.

Airway Assessment and Mouth Opening

The patient should be able to open the mouth wide so that the rigid tube can be manipulated for intubation. Often, patients with prior head and neck tumors who have received radiation, will likely have limited mouth opening and not be a candidate for rigid bronchoscopy. The patients should ideally have at least 3-4 cm of mouth opening.²⁴

The oral cavity should also be examined for any loose teeth, oral lesions, or dentures as these may get in the way during the intubation. At times teeth can break off and fall into the oral cavity during the intubation. It is also good practice to note the old scars in the mouth, so the proceduralist can differentiate from any new oral trauma that may be caused during the intubation.

The patient's neck circumference and length should also be assessed. If the patient has a wide and short neck, then the intubation is likely to be difficult. Similarly, if the patient is obese, then the reduced functional residual capacity and soft tissue prominence in the upper airway also make for a challenging intubation. In these patients, a back-up plan for the airway should always be present in case the rigid intubation is difficult, such as placing an endotracheal tube, bag-mask ventilation or a laryngeal mask airway placement.

The proceduralist and anesthetist should also assess the cervical spine of the patient. The rigid intubation requires that the patient's neck be extended for the intubation. If the patient's **cervical spine** is not stable, or they cannot extend it well, then they would be a difficult intubation or may not be considered a candidate for rigid bronchoscopy.²⁴

Other key physical exam findings to assess are **stridor, exercise tolerance, and ability to lie flat**. If a patient has stridor at rest and cannot lie flat, it usually indicates >80% central airway obstruction and suggests that ventilation during the procedure will be challenging. In contrast, the absence of stridor, combined with good exercise tolerance and no orthopnea, generally predicts that airway management and ventilation will be straightforward.

Comorbidities Evaluation

Chronic conditions usually will not play a major role in deciding about anesthetic risk, as predominantly the airway lesion is a life-threatening problem that must be dealt with. The chronic conditions may be a consideration if they are affecting the ventilation, such as chronic obstructive pulmonary disease, or interstitial lung disease. Ideally, good blood pressure control, glycemic control and control of other comorbidities should be done if the procedure is non-emergent. However, often these issues have to take back seat, as the risk is dictated by the primary central airway problem, rather than these comorbidities.²⁴

At times, these patients have underlying coronary artery disease and are on anti-platelet therapies or have had thromboembolic disease requiring anticoagulation. It should be ensured with the proceduralist that these medications have been held in a timely manner. Anticoagulants should typically be stopped 5 days before rigid bronchoscopy for warfarin,

and 24–48 hours for direct oral anticoagulants (DOAC), depending on the agent, renal function, and bleeding risk.

Pre-procedural blood product arrangement is usually not mandatory if the patient's hemoglobin (Hb) is above 10 mg/dL. However, if the patient's Hb is < 8 mg/dL, one or two units of blood transfusion can be considered to optimize the oxygen delivery prior to the procedure. Blood products for intraprocedural bleeding are likely not needed, as the airways do not have the capacity for large blood loss.

Patients with active arrhythmias, acute myocardial infarctions, aortic dissections, or shock requiring medium to high dose vasopressors, are not to be considered for rigid bronchoscopy due to high probability of a poor outcome. Before all rigid bronchoscopies, the patient's short and long-term survival should be considered. If the underlying conditions predict a high short-term mortality, then the rigid bronchoscopy would unlikely change the outcome and may lead to unnecessary morbidity and cost.

Procedural Anesthesia

The goals for anesthesia during rigid bronchoscopy are to achieve deep sedation, immobility of the patient, adequate oxygenation, ventilation, and hemodynamic stability.^{23,24} Close collaboration between anesthesiologists and bronchoscopists is essential to ensure optimal procedural outcomes.

Deep Sedation and Immobility

Rigid bronchoscopies should be performed with total intravenous anesthesia (TIVA) and paralytics.^{20,28,29} Any combination of TIVA can be used, such as propofol, dexmedetomidine, nalbuphine, ketamine or midazolam.^{20,28,30,31} The dose of sedative agent used should be adjusted to achieve deep sedation. Commonly, propofol infusions are effective for rigid bronchoscopies and can be titrated quickly to achieve deeper sedation.

Any neuromuscular blocking agent can be used.²⁹ The proceduralist should inform the anesthetist of the expected duration of the procedure. Short procedures such as removal of FBs or balloon dilations can be performed within 10 to 20 minutes. However, procedures such as tumor debulking and stent placements require more time such as 1 to 2 hours. The choice of neuromuscular blocking agent can be adjusted according to the expected procedure time. Rocuronium may perform better than succinylcholine.³²

The choice of induction during intubation should also be discussed between the proceduralist and anesthetist. For airways that are an easy intubation, a moderate duration paralytic agent such as rocuronium or cisatracurium can be given for the intubation process. However, for threatened airways that may be difficult to ventilate, giving succinylcholine and attempting the rigid intubation may be appropriate, if in case the first intubation pass is unsuccessful, then bag-mask ventilation can be attempted in an unparalyzed patient as the succinylcholine wears off. It is important that the patient is deeply sedated and appropriately paralyzed for the intubation and the duration of the procedure. If the patient coughs excessively or moves during the intubation or the procedure, it can lead to unwanted trauma or hypoxemia.³³

Ventilatory Techniques

In a patient requiring an advanced bronchoscopic procedure, there are generally 3 different options of an advanced airway. The first option is rigid bronchoscopy, and that is the most common airway tool, as it provides rapid control of therapeutic interventions. However, other options include an endotracheal tube or an i-GEL laryngeal mask airway. In certain limited cases such as a distal right or left main stem balloon dilatation or stent placement, an

endotracheal tube can be placed. For benign proximal tracheal stenosis, in which high peak pressures will not be needed to ventilate a patient, an i-GEL laryngeal mask airway can be placed.³⁴ Similarly for small FB removals, endobronchial ultrasound (EBUS), and navigational bronchoscopy, an i-GEL can be used.³⁵

There are two main ways to ventilate a patient through a rigid bronchoscope.

Controlled assist ventilation, or jet ventilation (manual or high-frequency automatic.²⁴ Both techniques have its caveats and benefits, which the anesthetist should be aware about. Other less commonly used techniques are apneic oxygenation and spontaneous assisted ventilation.²⁴ Spontaneous assisted ventilation has shown to be equally safe with TIVA, however it has a slightly higher incidence of complications compared to controlled assist ventilation.^{28,36} Apneic oxygenation is now discouraged and is not a common practice.²² Our recommendation is to use either controlled assist or manual jet ventilation based on availability and experience. **Controlled assist ventilation** is easier to connect, however may not provide adequate ventilation if there is a high-grade obstruction in the airways.

For assist control ventilation, a side port is used to connect the ventilator to the rigid tube, similar to an endotracheal tube (see rigid bronchoscopy equipment below). A set tidal volume is applied to deliver ventilation through the barrel of the tube. There are two issues faced with this method. The first issue is that since there is no cuff on the rigid tube and the proximal port is open for the rigid scope; there is a high leak in the system. Therefore, most of the volume is not delivered to the alveoli. The second issue is that these patients usually have a high-grade airway obstruction which needs high peak pressures to bypass the obstruction and ventilate the distal lung. Commonly used pressures through the assist control methods usually do not provide sufficient pressures to effectively ventilate past the obstruction. If this method of ventilation is used, it may be appropriate in cases when there is no major airway obstruction such as when a FB may need to be removed. If assist control ventilation is used with a rigid scope, then the oral pharynx must be tightly packed with gauze to reduce the chances of air leak. That is a cumbersome process and still leads to a significant air leak. Overall, assist control ventilation is easy to set up, however may not be effective to ventilate patients with high-grade airway obstructions.²²

Most proceduralists prefer using **jet ventilation** during rigid bronchoscopy^{20,24}. Through the rigid tube's side port, the tubing of the jet ventilator is connected. The jet ventilatory breaths can be delivered manually using a Sanders valve or via an automated ventilator at supraphysiologic respiratory rates.^{22,24} For manual jet ventilation, the anesthetist is responsible for delivering breaths with the jet ventilator. Usually, the setting of the jet ventilator is set at a pressure of 20-25 PSI.²² The anesthetist delivers an inspiratory breath every 3 to 5 seconds. The anesthetist should hold down the jet ventilator lever for about 1 to 1.5 seconds while observing for chest rise, and then wait for 2-3 seconds for the chest to passively recoil before delivering the second breath.²² This would ensure appropriate ventilation along with allowing the patient to expire carbon dioxide. During jet ventilation, it is essential to avoid creating a closed system to reduce the risk of barotrauma and aspiration. If hypoxemia or desaturation occurs, the scope can be briefly withdrawn into the trachea to allow bilateral lung ventilation. During this maneuver, bronchial secretions from the healthy lung can be cleared in order to improve the oxygenation during the bronchoscopy.

Anesthetic Complications Related to Rigid Bronchoscopy

The main complication associated with rigid bronchoscopy is difficulty in ventilation leading

to hypoxemia and hypercapnia. Depending on the airway obstruction and the mode of ventilation, there needs to be vigilance and communication between the anesthetist and the proceduralist on how to handle these complications. Mild hypoxemia and hypercapnia are acceptable in these procedures. Significant hypoxemia is not frequent and happens in less than 5%, if ventilatory parameters are taken care of and no procedural complications occur.^{25,37} With rigid bronchoscopy, end-tidal CO₂ cannot be measured, however transcutaneous capnography or arterial sampling can provide information.²⁰ During rigid bronchoscopy with jet ventilation, elevated CO₂ is more common than low oxygen, with end-tidal or arterial CO₂ levels typically ranging from 45 to 60 mmHg.^{24,37} A PCO₂ of up to 100 is also acceptable and will resolve once the rigid procedure is completed, however PCO₂ of greater than 100 has shown to worsen outcomes.³⁷ In most patients an arterial line or frequent blood gas monitoring is not required. However, where the anesthetist feels that the patient is not ventilating adequately, an arterial line or frequent blood gas sampling can be performed.

The other complication that can be seen with jet ventilation is barotrauma. However, when pressure such as 20 to 30 PSI are used, then barotrauma is a rare complication.²⁴ In patients with limited lung reserve this can be a significant complication. The anesthetist and the procedure list should be aware of this if there are any hemodynamic or ventilatory changes.

The rigid tube can also lead to an airway perforation.²⁴ If such an event is to occur, then there would be a high air leak into the mediastinum or the pleural space. Complications such as these can be quite complex and an attempt can be made to bypass the perforation with the tube to ventilate the distal airway. Other measures such as placement of a stent can be done by the proceduralist to cover the airway perforation.

Uncommonly, the rigid tube can put mechanical pressure on the surrounding structures. This mechanical pressure on the great vessels can impair cardiac output and venous return. This can sometimes lead to significant hypotension, arrhythmias and cardiac arrest. If mechanical pressure of the rigid tube is felt to be the causative factor, repositioning of the rigid tube should be done or removal of the tube and ventilating with a standard endotracheal tube till the patient is stabilized.

With any form of cautery- such as APC or electrocautery, and high oxygen content in the airways, there is a risk of airway fire (see APC section below).²² During assist control ventilation, the FiO₂ should be kept below 40%, and during jet ventilation, the anesthetist should pause any breath delivery when cautery is being performed. Therefore, the anesthetist and proceduralist should communicate very closely during this process to ensure that ventilation is held at the appropriate time and resumed when the cautery process has been paused.

Airway interventions can lead to airway bleeding, however large volume bleeding is rare.^{22,38} It is the job of the proceduralist to control the bleeding with the tools on hand. However, if the bleeding is significant and the patient is desaturating due to significant blood in the airways the anesthesiologist should always be prepared to place a double lumen endotracheal tube to ventilate the normal airway and lung.

Post Procedure Care

The goal of post procedure care should be to extubate the patient. The patient should ideally be extubated in the operating room soon after completion of the procedure. If the airway obstruction has been relieved, then the patient's underlying respiratory issue should have improved. Therefore, most patients need less ventilatory support than prior to the

procedure.

As a standard practice, if the patient has had a successful procedure, endotracheal intubation should be avoided in the recovery phase. Placement of an i-GEL or laryngeal mask airway is preferred or the anesthetist can extubate to a face mask.^{22,38}

There may be certain issues faced by the anesthetist after extubation. At times, there are issues with retained secretions, airway edema, or bronchospasm, which can lead to respiratory distress. Nebulizing, oxygen therapy, encouraging the patient to clear their airway, may improve the bronchospasm slowly. Steroids can be used on case-to-case basis.

If there is significant respiratory failure post-procedure then non-invasive ventilation or high-flow nasal oxygenation should be tried. After few days of the procedure, secretions and airway edema improve, and these can be weaned off. In severe cases, endotracheal intubation can be considered. However, a discussion should be done with the proceduralist to ensure that there is no residual obstruction for which a repeat airway exam should be performed.

Most patients have a rapid recovery after rigid bronchoscopy with therapeutic interventions. These patients can return to their baseline or sometimes better than their baseline soon after the procedure. If the intervention is successful, the respiratory failure or symptoms should be clinically better than prior. Many patients can be discharged within a few hours of the procedure, like a daycare setting. However, some patients with respiratory failure may require intensive care or step-down care.

Rigid Bronchoscopy Equipment, Procedure and Setup

Rigid bronchoscopy is a valuable tool for managing central airway pathology due to its ability to secure the airway and maintain ventilation throughout the procedure. The scope's large-caliber working channel allows simultaneous use of multiple instruments, and it supports larger suction devices and forceps for the removal of debris, thrombus, and foreign bodies. A key limitation is that the rigid bronchoscope cannot reach beyond the proximal bronchi. To overcome this, a flexible bronchoscope is often introduced through the rigid scope to assess and treat more distal airways.

Equipment

The choice of equipment for rigid bronchoscopy usually depends on local expertise and institutional resources.³⁹

The basic equipment includes:

1. Rigid barrel (tracheoscope or bronchoscope).
2. Visualizing equipment (telescope, light cable, and camera, with real time images displayed on a video monitor).
3. Accessory instruments, biopsy forceps, suction, electrocautery unit etc.

Rigid bronchoscope

The rigid bronchoscope is a hollow stainless-steel tube (see figure 3 and 4). A rigid telescope is inserted through it. It's also known as an open-tube, straight, or ventilating bronchoscope.

Rigid bronchoscopes come in various sizes:

- External diameter: 2-14 mm
- Wall thickness: 2-3 mm
- Length: 33 cm (tracheal scope) and 43 cm (bronchial scope)

Rigid bronchoscopes have a uniform diameter throughout, except for the beveled or tapered tip, which lifts the epiglottis during intubation and facilitate dilation of airway strictures. Rigid bronchoscopes are typically round or oval in cross-section. The proximal end features a central opening and sometimes external side ports for suction, tools (like electrocautery, laser equipment), and ventilation. Some scopes have shaft fenestrations for contralateral lung ventilation. Rubber or silicone caps fit on proximal ports to reduce air leaks, and pinpoint piercings allow for accessory instruments.

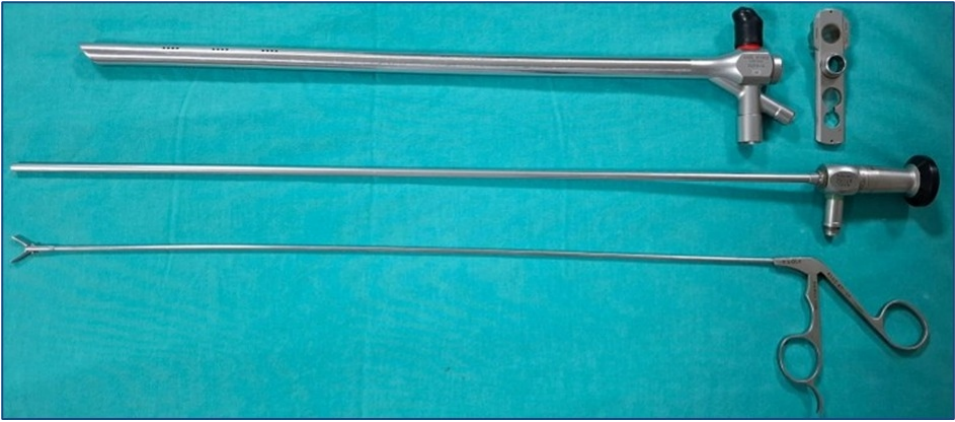


Figure 3. Rigid bronchoscope: Distal beveled edge, barrel with ventilation slits and proximal 90° angle side port for standard anesthetic circuit for continuous/intermittent insufflation and spontaneous ventilation and 30° angle Luer-lock connector for jet ventilation (top left), adapter for passage of instruments (top right), 0-degree rod-lens telescope (middle), and rigid biopsy forceps (bottom) used for tissue biopsy, tumor debulking, or FB retrieval.

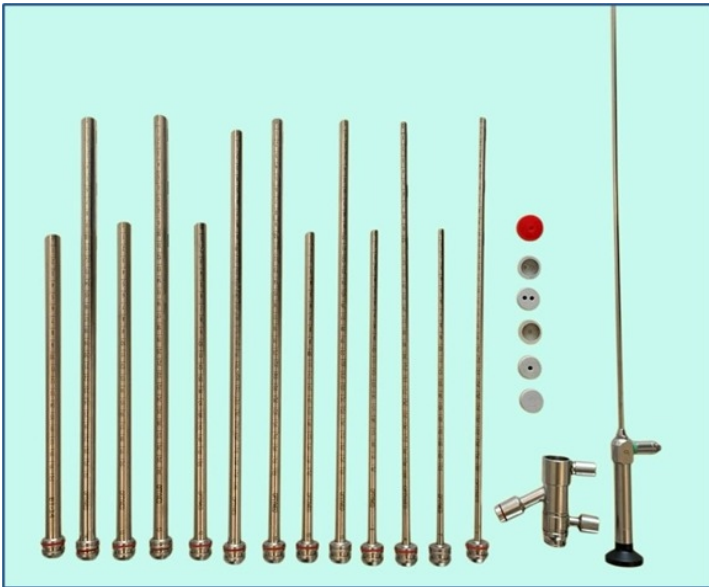


Figure 4. Components of a standard rigid bronchoscopy set including showing ventilating tubes with obturators, multifunction ventilation head, rigid telescope, and sealing caps for airway instrumentation.

Larger bronchoscopes are better suited for tracheal procedures, such as placing large stents or managing proximal airway lesions, while smaller bronchoscopes are preferable for distal bronchial interventions. During a procedure, scopes can be sequentially exchanged for larger sizes to accommodate bigger instruments or to dilate airway stenoses safely, minimizing the risk of mucosal injury. Rigid bronchoscopes are manufactured by EFER Endoscopy (La Ciotat,

France), Richard Wolf (Knittlingen, Germany), Karl Storz (Tuttlingen, Germany), and Dutau-Novatech (La Ciotat, France). Despite differences in design, all of these scopes use the same standard components: a rigid tube, illumination system, and optical system. The Texas rigid bronchoscope is the first fully integrated system that houses a semi-flexible endoscope inside. Its key advantage is preserving the full inner lumen of the rigid scope, with the semi-flexible endoscope attaching through a dedicated internal channel.

The proximal end of a rigid bronchoscope houses multiple ports and a **hollow channel** for the telescope connected to a bronchoscopy tower via camera, with **lateral ports** for connecting light sources and ventilation adapters.

Visualizing Equipment (Telescope, Light Source, Video Monitor)

Rigid telescopes with varying angles (0-180°) are used through the bronchoscope to visualize airways, including trachea, mainstem bronchi, and lobe origins. Alternatively, a flexible bronchoscope can be passed through the rigid scope for visualization. Most physicians only need a direct-view rigid telescope since a flexible bronchoscope eliminates the need for angled scopes when examining the sides of the central airways or treating lesions in the upper lobes.⁴

The light source, typically a xenon or halogen lamp, is delivered either by inserting it directly into the rigid bronchoscope or by attaching it to the telescope.

Video equipment (figure 5) is great for teaching, documenting, and letting multiple people view the procedure on the monitor. **Cameras (single- or three-chip)** connect to the rigid telescope's eyepiece via direct connection, snap-on lenses, or C-mounts.



Figure 5. Rigid bronchoscopy trolley. From top to bottom: video monitor, camera processor, and light source.

Accessory Instruments

Accessory instruments used during rigid bronchoscopy include rigid biopsy forceps, foreign-body retrieval forceps/baskets, suction catheters, and devices for airway prosthesis insertion and removal, such as stents and procedure-specific equipment like CRE balloons etc. These instruments are typically introduced through the lumen of the rigid bronchoscope via a silicone cap or open port. When indicated, these instruments can be introduced via a flexible bronchoscope passed through the rigid scope (figures 6 and 7).

Setting for Rigid Bronchoscopy and Preparation

Rigid bronchoscopy is performed under general anesthesia, most commonly in an operating room. It may also be carried out in an intensive care unit (ICU) with appropriate expertise and monitoring, or in a bronchoscopy suite equipped with full anesthesia support.^{40,41}

Patient preparation requires an 8-hour fast for solids, with clear fluids permitted up to 2 hours before the procedure.

Pre-procedure checks include a formal time-out, assessment for difficult intubation and cervical spine stability, and confirmation of an adequate seal for mask ventilation.



Figure 6. Rigid bronchoscopy forceps distal tips showing left: alligator jaw, middle: smooth cup jaw, right: rat tooth jaw for biopsy and foreign body retrieval.

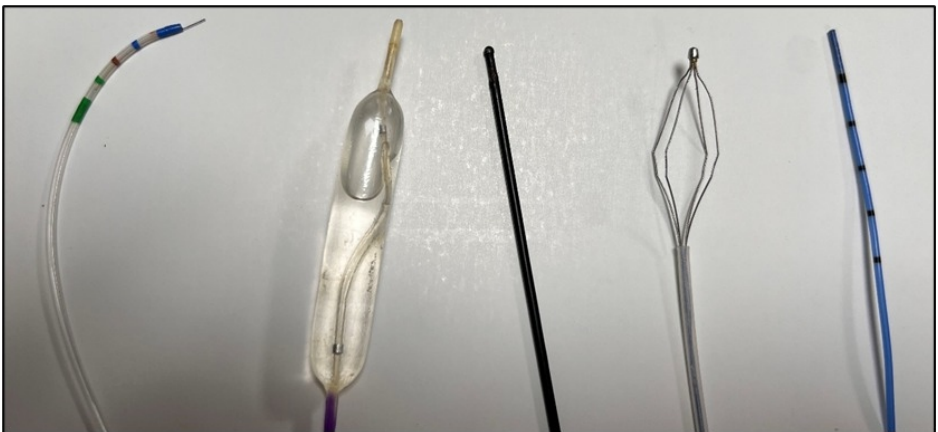


Figure 7. Distal tips of instruments used in rigid and combined flexible-rigid bronchoscopy, shown left to right: electrocautery knife, CRE balloon dilator, electrocautery probe, foreign body retrieval basket, and APC probe.

The airway management plan should be discussed with the anesthesiologist to ensure a secure airway can be maintained in the event of complications before, during, or after rigid scope insertion. **Equipment preparation** involves confirming functioning suction and patient monitoring, establishing intravenous access and having necessary medications available, and ensuring a range of rigid bronchoscopes, both tracheal and bronchial sizes, is ready. The required procedural instruments and accessories should also be organized according to the planned intervention.

Patient Preparation and Positioning

A thorough pre-procedural assessment is essential, including airway examination, dental status, mouth opening, and history of neck trauma or cervical spine disease. The procedure is performed with the patient supine, head slightly hyperextended in the sniffing/intubation position to align the pharyngeal and laryngeal axes. A shoulder roll can facilitate hyperextension when needed. The operating table should be horizontal and at a height that optimizes ergonomics for both the bronchoscopist and anesthetist. Neck mobility must be checked to ensure the head can be safely turned toward the contralateral shoulder during main bronchus intubation without free movement. Before induction, the team should brief on equipment availability and roles.

The Rigid Bronchoscopy Procedure Techniques

Several techniques can be used for intubation.^{41,42}

Method 1: Direct Intubation with Telescope and Maneuvering

This is the preferred technique. A 0° rigid telescope is inserted into the rigid bronchoscope to visualize the beveled tip. Standing behind the supine patient with the head partially extended, the bronchoscopist holds the scope with the dominant hand. The middle finger of the non-dominant hand is used to protect the upper dentition during insertion, preventing dental trauma. Preferably, a saline-soaked gauze sponge or a dedicated dental guard should be interposed between the teeth and the bronchoscope barrel for protection.

The scope is inserted into the mouth with the bevel anterior, advanced along the tongue, and the epiglottis is identified and lifted. The beveled tip is slid under the epiglottis, advanced to visualize the arytenoids and vocal cords, then rotated 90° laterally to enter the trachea without laryngeal trauma (figure 8). Once past the cricoid cartilage, the scope is rotated to the six o'clock position to align the bevel with the posterior tracheal wall, and ventilation is initiated through the proximal ventilatory port. When entering a main bronchus, the head of the patient needs to be turned towards the contralateral shoulder.

Once the rigid bronchoscope has been introduced into the trachea or main bronchus, it is advanced and withdrawn using controlled, gentle rotational movements. This technique allows the beveled tip to navigate the airway lumen while minimizing mechanical trauma to the respiratory mucosa and underlying cartilaginous rings. The rigid bronchoscope is manipulated through three primary movements to navigate and inspect the airway. It can be advanced and withdrawn longitudinally to assess proximal and distal segments, swept laterally to visualize the entire airway wall, and rotated clockwise or counterclockwise, often in a spiral motion, to negotiate curves and direct the tip toward the target lesion. When the target lesion is visualized, the scope is positioned and stabilized directly over it to provide a stable working channel and optimal visualization. Subsequent therapeutic interventions are then performed through the scope's lumen according to the specific pathology identified. Examples include extraction of aspirated FBs with grasping forceps or baskets, debulking of endobronchial tumors using forceps, electrocautery, or laser, and dilatation of benign or malignant stenoses with balloons or rigid dilators. Physicians who prefer using the rigid scope don't rely on it alone, they acknowledge the value of supporting techniques and the central role the flexible scope (figure 9) plays during a procedure especially airway clearance and collecting specimens (washings, lavage, biopsies).

Method 2: Laryngoscope-Assisted Intubation

As an alternative, a laryngoscope is used to visualize the vocal cords. The rigid bronchoscope is passed through the mouth and vocal cords like an endotracheal tube (ETT), kept midline and rotated slightly to avoid trauma. Once in the trachea, the laryngoscope is removed, the telescope is inserted, and the bronchoscope is advanced and rotated to the six o'clock position for ventilation.

Modifying Intubation Techniques for ETT or Tracheostomy

Preexisting ETT: Pass rigid bronchoscope alongside ETT, suction secretions, deflate ETT cuff, remove ETT, and advance bronchoscope into trachea.

Preexisting tracheotomy: Intubate through stoma (e.g., laryngectomy patients). Insert

bronchoscope directly through stoma, avoiding posterior tracheal wall trauma.

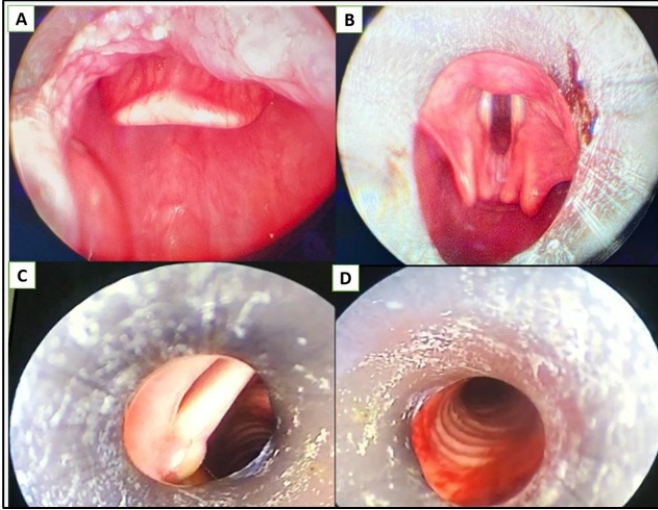


Figure 8. Sequential endoscopic views during rigid bronchoscopy intubation: (A) Oropharyngeal view showing epiglottis (B) Laryngeal view with the vocal cords abducted (C) Anterior deflection of the rigid bronchoscope to 90° to displace one vocal cord for glottic entry (D) Intratracheal view showing tracheal rings distal to the scope tip.



Figure 9. Rigid bronchoscopy performed under general anesthesia in an operating room. After insertion of the rigid bronchoscope via the oral cavity, a flexible bronchoscope is passed through its barrel. The anesthetist maintains ventilation and monitors the patient's vital signs throughout the procedure.

Post-procedure Disposition Following Rigid Bronchoscopy

Post-procedure disposition (table 2) following rigid bronchoscopy varies with the indication and patient comorbidities. For uncomplicated cases in otherwise healthy individuals, such as FB removal in a stable patient, the procedure is often performed on a daycare or ambulatory basis, allowing discharge within a few hours once airway patency, oxygenation, and hemodynamic stability are confirmed. In contrast, patients with underlying respiratory disease, compromised pulmonary reserve, or acute respiratory failure typically require a higher level of care post-operatively.⁴³ These individuals may need admission to an ICU for mechanical ventilation and close monitoring, or to a step-down/high-dependency unit for supplemental oxygen, airway clearance, strict vital signs monitoring and observation for complications such as airway edema, bleeding, or pneumothorax.^{43,44} Therapeutic rigid bronchoscopy typically leads to clinical improvement in most patients. Because of the need for airway monitoring, most are kept for overnight observation, with ICU admission reserved for complicated cases. Same-day discharge is uncommon after this procedure. A post-procedure chest radiograph is recommended after dilation, biopsy, tumor debulking or stent placement to confirm resolution of atelectasis, rule out complications like pneumothorax, and verify airway patency.^{43,44,45} In cases where imaging shows abnormalities due to post-obstructive infection, follow-up radiography is advised at 6 weeks to 3 months after foreign body removal or airway clearance to document radiologic resolution.⁴³

Table 2: Post-procedure disposition following rigid bronchoscopy.

Disposition	Indications	Key Actions / Monitoring	Duration / Discharge Criteria
Post-operative Recovery Area	All patients immediately post-procedure	Continuous SpO ₂ , ECG, BP, respiratory rate; assess airway patency, stridor, bleeding, oxygenation	Minimum 30–60 minutes; transfer when stable vitals and awake
Ward / HDU	Uncomplicated diagnostic/minor therapeutic procedure; stable vitals; SpO ₂ >94% on room air	CXR at 1–2 hours if dilation/biopsy/stent placed; NPO until gag reflex returns (2–4 hours); analgesia	4–12 hours observation; discharge when: stable vitals >1 hour, SpO ₂ >94%, pain controlled, CXR reviewed, escort present
ICU / HDU Admission	Significant bleeding/airway edema; post-massive hemoptysis or foreign body removal; post-procedure mechanical ventilation; unstable comorbidities	Close airway monitoring; repeat CXR, ABG as needed; IV steroids and nebulized adrenaline for edema	12–48 hours; discharge when hemodynamically stable, no respiratory distress, off ventilation
Direct Discharge Home	Rare; only low-risk diagnostic cases in healthy outpatients with responsible adult escort	CXR normal; no sedation residual; no bleeding; able to tolerate oral intake; written instructions given	Same day discharge; must meet all ward discharge criteria + escort present

Indications/ Clinical Uses (table 3)

Central Airway Obstruction (CAO)

CAO is a critical clinical condition defined by compromised airflow in the trachea or main bronchi, most commonly caused by primary or metastatic malignancies, benign tracheal stenosis, tracheomalacia, or FB aspiration. Using a flexible bronchoscope alone has limitations for treating CAO, especially tracheal lesions. Its narrow working channel may not control massive bleeding, and the small biopsy forceps can only remove tiny tumour fragments, making the procedure lengthy and cumbersome.⁴⁶ Rigid bronchoscopy is indicated for palliation or restoration of airway patency in malignant disease involving the central airways.^{4,47}

Recommended interventions include:

- Mechanical debridement
- Core debulking using rigid bronchoscope
- Forceps debulking
- Microdebrider-assisted tumor removal
- Heat ablative therapies, including:
 - Argon Plasma Coagulation (APC)
 - Electrocautery
 - Laser therapies
- Cryotherapy / cryodebridement
- Airway stent deployment, particularly silicone stents

Benign or malignant tumor obstruction (coring and debridement)

Malignant airway involvement can be intrinsic, when the tumor is inside the airway; extrinsic, when there's external compression; or mixed, when both endoluminal tumor and external compression are present.^{42,48} Bronchial obstruction can also cause complications like atelectasis, respiratory insufficiency or distress, and recurrent infections, which may interfere with chemotherapy and radiotherapy. Oncologic treatments rarely give quick symptom relief, so endoscopic therapy is a key adjunct for patients at all stages, neoadjuvant, adjuvant, and palliative.⁴

In principle, purely intrinsic involvement can often be managed with debulking techniques to remove the endoluminal tumor. Rigid bronchoscopy is the preferred approach in cases of respiratory failure from airway obstruction, as it rapidly secures the airway, maintains oxygenation, and allows direct treatment of the underlying obstructive lesion.⁶ Patients with malignant CAO (occurring in up to 20% of patients with bronchogenic carcinoma) typically have a poor prognosis, but intervention can improve performance status, quality of life, and physiological parameters.⁴⁹ Treatment depends on endobronchial obstruction type: dilation and stenting for extrinsic compression, and debulking plus stenting for mixed obstruction. Bronchial stents may be inserted as a bridge to chemo-radiotherapy or as a long-term solution for high endobronchial tumor recurrence risk. Bronchoscopic relief typically lasts 2–3 months, while stents remain patent for about 4 months before overgrowth, though this can be prolonged with effective oncologic therapy.^{50,51}

Debulking a tumor in the airway involves 3 steps: coagulating and **devascularizing** the tumor using thermal or non-thermal techniques, mechanical coring using the rigid bronchoscope's beveled edge to remove tumor fragments, and coagulating the tumor base. The process starts with coagulating the tumor, followed by mechanical coring with the bronchoscope, removing debris via suction, cryoprobe, or forceps, and controlling bleeding with bronchoscope pressure or methods like APC, enabling safer use of further thermal or ablative techniques (see below).^{52,53} Rigid bronchoscopy and mechanical debulking is safe and successful in up to 83% of cases of central airway tumors⁵⁴. Tumor debulking and recanalization of the trachea and main bronchi is recommended if the distal airway beyond the obstruction is open and supplies functional lung tissue and the pulmonary artery supplying that lung part is patent; if not, recanalization might increase dead space without improving function.⁵³

CT Chest with multiplanar 2D and 3D reconstruction methods and virtual bronchoscopy can display airways and parenchyma in a more anatomically familiar meaningful way (figure 13). Further radiological details should include assessment of airway patency distal to the stenosis, lesion diameter, length, and relation to nearby structures like vessels.⁵⁵ A successful endobronchial debulking procedure requires: localized disease with proximal obstruction (trachea, main bronchi), patent distal airway, functional bronchus and lung parenchyma, and pulmonary artery. Patient should have good performance status and short (<3 cm) symptomatic obstruction with total atelectasis.⁴

Bronchoscopic Ablative Therapies

Bronchoscopic ablative therapies for tumor debulking are broadly categorized into thermal, non-thermal, and mechanical techniques.

Thermal ablation modalities include laser therapy, electrocautery, argon plasma coagulation, endobronchial brachytherapy, and microwave ablation. These modalities produce tissue effects through heat-mediated changes in cellular structures, progressing from devitalization to desiccation, carbonization, and ultimately vaporization as temperature increases. Preferably monopolar, both monopolar and bipolar electric currents can be utilized for electrocautery. To minimize the risk of airway fire, the inspired oxygen concentration (FiO₂) should be reduced to <40% during thermal ablation procedures.

Electrocautery/diathermy is a contact-based thermal modality that enables tissue destruction, airway deobstruction, and rapid coagulation through heat generated by the transmission of high-frequency electric current. High-frequency electric current causes coagulation at lower temperatures and tissue vaporization at higher temperatures. The extent of tissue destruction depends on the power and duration of application, the surface area of contact, and the tissue's density and moisture content. In the airways, a monopolar technique is used, where current passes from the applicator through the body to a return electrode on a limb. Low voltage, low power, and high current settings produce coagulation, whereas high voltage and low current settings produce carbonization or a cutting effect. Most electrocautery devices used through the bronchoscope employ a blended waveform that combines both cutting and coagulation.⁵⁶ Endobronchial electrocautery is safe in experienced hands and effective for debulking endobronchial tumours, early-stage lung cancer, and benign airway tumours and stenoses, with all indications supported by Level 3 evidence.⁵⁷

Start with a low energy setting of around 20 W (range of 10–40 watts) and test it on normal mucosa before treating the lesion. Treatment duration directly affects the depth of tissue damage. At 30 W, tissue necrosis depth increases with application time, ranging from 0.1 mm after 1 second to 1.9 mm after 5 seconds. Prolonged coagulation of 3–5 seconds can damage underlying cartilage.⁵⁸ A variety of instruments (figures 10 and 11) can be employed, including snares, knives, probes, and forceps, allowing targeted application for both hemostasis and tumor debulking.^{4,40,48} An electrocautery knife is particularly effective for resecting benign webs. A probe can be used for superficial tumours treatment, while a snare is useful for debulking large volumes, especially polypoid tumours (figures 12 and 13). It may be necessary to remove the tumour in several sections before the airway is opened. Larger volumes of tumour can be cleared from the airway using suction, grasping or biopsy forceps, or a cryoprobe. Generally, power settings should be 30 W for punch biopsy and snare resection, 20 W for probe use, and 10 W for the needle knife.⁵⁹

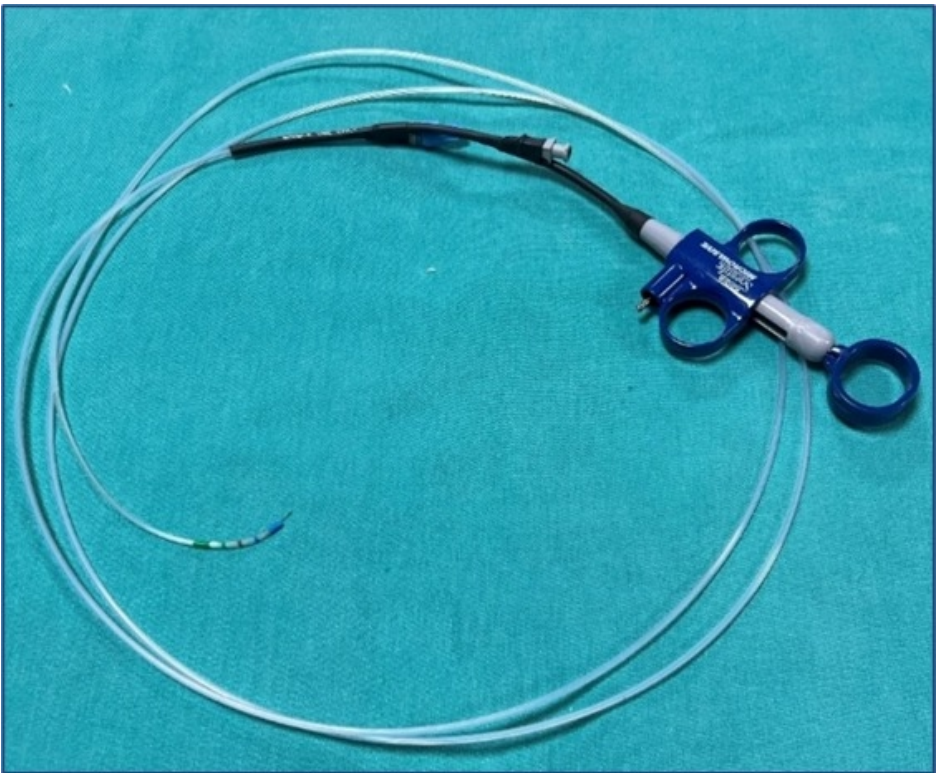


Figure 10. Flexible electrocautery knife for bronchoscopy, showing the catheter with needle tip and handpiece. Used to cut, ablate, and coagulate tissue to relieve airway stenosis.

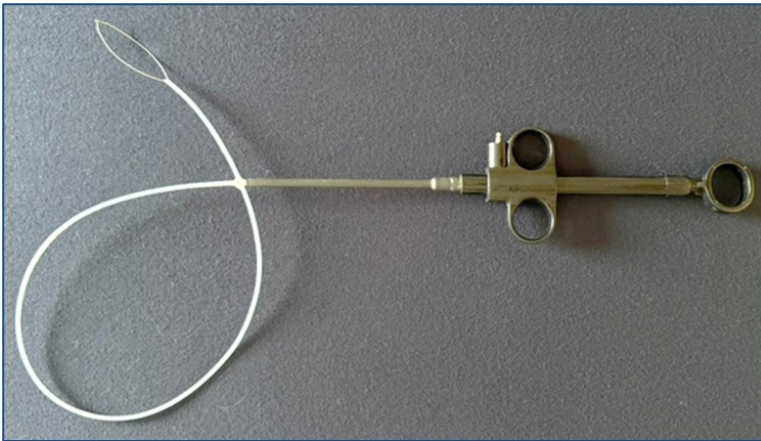


Figure 11: Flexible bronchoscopy electrocautery snare with insulated sheath, wire loop, and pistol-grip handle for endobronchial lesion resection and hemostasis.

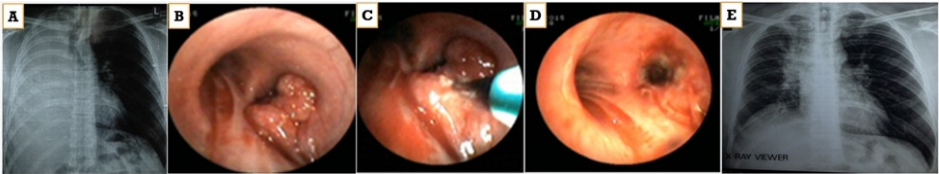


Figure 12. A 36-year-old male, non-smoker, presenting with recurrent hemoptysis and cough, underwent bronchoscopic tumor (adenocarcinoma) debulking using electrocautery: (A) CXR-PA showing an opaque right hemithorax with ipsilateral mediastinal shift, consistent with right lung collapse (B) Bronchoscopic view demonstrating an endobronchial tumor in the right main bronchus (RMB) causing complete luminal obliteration (C) Application of electrocautery forceps to the tumor for electrical coagulation and devitalization (D) Bronchoscopic image after debulking showing restored patency of the RMB (E) Post-procedure CXR-PA demonstrating resolution of the right hemithorax opacity with residual right hilar prominence due to lymphadenopathy.

When undertaking snare resection, intermittent bursts of electrocautery of not more than 2 seconds duration should be used while carefully closing the snare against resistance. Mucus, debris, and blood should be continuously cleared to prevent current leakage. Bleeding and airway fire (reduce FiO_2 to 0.4) are the main complications of diathermy. It should be avoided in patients with pacemakers when possible, and return electrodes should not be placed over skin covering metallic joint prostheses.⁵⁹

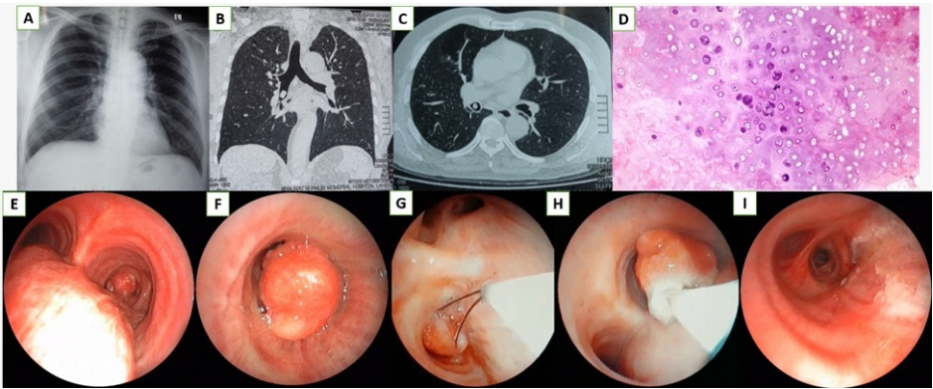


Figure 13. A 62-year-old-male (ex-smoker) presented with intractable cough unresponsive to treatment, (A) Clear CXR-PA (B and C) Multiplanar CT thorax (coronal and axial reconstruction images) showing a well-circumscribed, smooth-to-lobulated soft tissue mass in the bronchus intermedius with normal distal airway and lung parenchyma with no atelectasis, mucus plugging, post-obstructive pneumonia, or metastases (D) Histopathology consistent with benign endobronchial chondroma (E) Bronchoscopy carinal image showing tumor in bronchus intermedius (F) Close-up tumor view (G) Electrocautery snare application around the base of the tumor (H) Post-electrocautery snare resection with the excised tumor being retrieved (I) Post-resection bronchoscopic image showing a clear airway; the tumor base was further treated with electrocautery.

Argon Plasma Coagulation is a non-contact thermal ablation technique in which argon gas is expelled from a probe and exposed to a high-voltage electric current at the probe tip (figure 14). Upon contact with the current, the argon gas becomes ionized to form plasma, which then conducts a monopolar electric current to the target tissue (figure 15). This results in superficial tissue coagulation and hemostasis with limited depth of penetration, making it particularly suitable for managing superficial lesions and controlling bleeding in the airway.⁶⁰

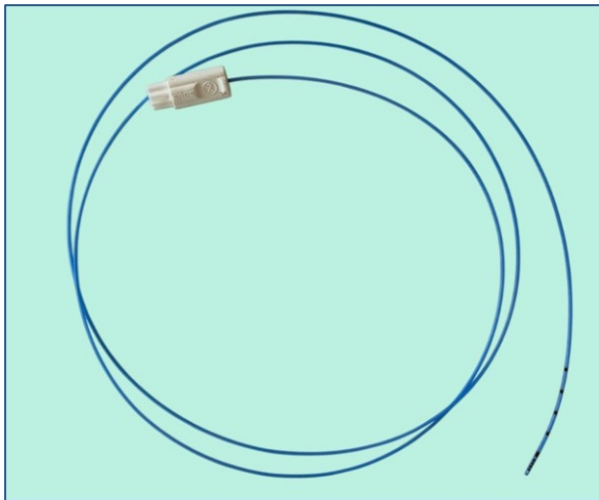


Figure 14. Flexible insulated APC probe/catheter with a proximal connector, central lumen for argon gas delivery, and a distal electrode tip that emits ionized argon plasma for non-contact coagulation.

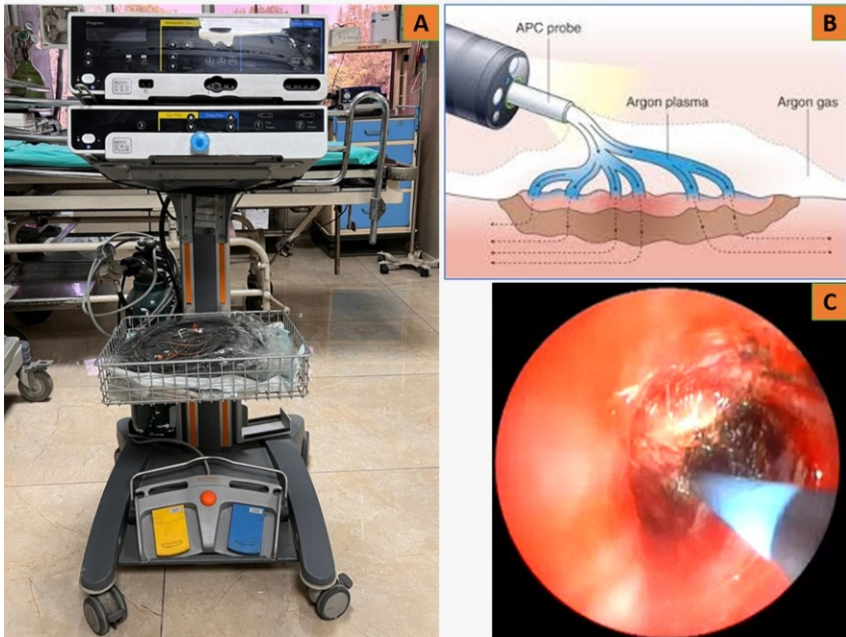


Figure 15. (A) Electrocautery unit (B) Delivery of ionized argon gas through an APC probe to achieve non-contact tissue coagulation (C) Bronchoscopic view of APC for airway tumor debulking

APC is a non-contact thermal ablation modality that operates within a 10–80-watt range, though 15–25 watts is generally used for precise coagulation. APC requires a high-frequency generator, argon gas source (cylinder), return electrode, and a flexible catheter with a monopolar tungsten electrode. The catheter, delivers argon at 0.3–2.0 L/min while the generator sends high-voltage current to the tip. This creates an argon plasma “spray” that coagulates tissue by following the path of least resistance to the return electrode. The argon gas flow should be kept as low as possible, typically 0.2 to 0.4 L/min, to minimize the risk of gas embolism and barotrauma. Energy is delivered in short bursts of 2–5 seconds from a distance of 2–8 mm from the target tissue, resulting in a superficial depth of penetration of 1–3 mm. It is applied via a flexible probe, 1.5 to 3.2 mm in diameter. For safety (to avoid risk of fire), the probe tip should be kept >2 cm distal to the bronchoscope and several centimeters beyond the endotracheal tube. APC is used for debulking both benign and malignant exophytic endobronchial tumours, as well as granulation tissue. Due to its limited depth and excellent hemostatic properties, APC is best suited for treating short, flat, intraluminal obstructing lesions and for controlling bleeding, including hemoptysis (figure 16). Similar to electrocautery and laser, an FiO_2 of <0.4 is recommended during APC to reduce the risk of airway fire.⁶¹



Figure 16. A 68-year-old male, cigarette smoker, presented with exertional dyspnea and recurrent hemoptysis (A) CXR showed an opaque right hemithorax with ipsilateral mediastinal shift (B) Bronchoscopy revealed a tumor in the right main bronchus causing complete occlusion (C) APC treatment was performed via rigid bronchoscopy, and the tumor was debulked (D) Post-debulking bronchoscopy showed a clear airway (E) Post-procedure CXR demonstrated significant radiological improvement.

Laser is a thermal ablative modality that is less readily available due to high cost. Its tissue effect depends on multiple factors, including wavelength and target tissue characteristics, exposure time, laser power, and the distance between the laser fiber and the target. Common laser types used in bronchoscopy include diode, CO₂, Nd:YAP, KTP, and Nd:YAG. Laser therapy is best suited for central, short segment (<4 cm) endobronchial lesions located in the trachea or main bronchi, particularly those with an exophytic appearance and a recent onset of airway collapse within 4–6 weeks.⁶²

Non-thermal options comprise cryoextraction/cryotherapy and photodynamic therapy. Cryotherapy achieves tissue destruction through repeated freeze-thaw cycles. Freezing tissue to minus 20°C to minus 50°C leads to the formation of intracellular ice crystals, resulting in >90% cell death. Tissue is then allowed to thaw slowly, which promotes growth of intracellular crystals prior to melting and enhances tissue destruction.⁶³ For debulking large endobronchial tumors, a combination of cryoadhesion and cryoablation techniques may be used. The extent of freezing is monitored by visualizing the halo of ice around the probe tip (figures 17 and 18). When the halo stops enlarging, freezing should be terminated and the tissue allowed to thaw. A typical protocol consists of an initial freeze for approximately 1 minute, followed by three freeze-thaw



Figure 17. Cryotherapy machine (left) with cryoprobe in the equipment basket for bronchoscopic use; cryoprobe tip in contact with chicken meat (middle) demonstrating freezing (spreading halo) at the probe tip; schematic illustration depicting cryotherapy application to an endobronchial lesion demonstrating ice-ball formation at the probe tip (right).

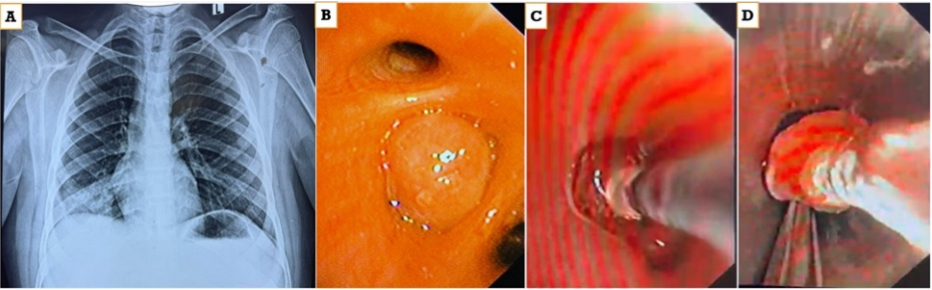


Figure 18. A 16-year-old male with benign endobronchial leiomyoma in the right lower lobe: (A) Chest radiograph PA view demonstrating post-obstructive pneumonic infiltrate in the right lower zone (B) Bronchoscopic image of the right lower lobe showing a solitary endobronchial mass occupying the antero-basal, lateral basal, and posterior basal segments (C) Application of a cryoprobe to the tumor with visible halo of ice forming over the lesion (D) Cryoextraction of the tumor through the barrel of a rigid bronchoscope.

cycles at the same site. The probe is then repositioned 5–6 mm and another three freeze-thaw cycles are performed. This sequence is repeated until the entire endobronchial lesion has been treated. For cryoextraction, the cryoprobe is placed in contact with the target tissue and activated to freeze onto the tumor surface. The bronchoscope and adherent cryoprobe are then withdrawn swiftly, removing the frozen tumor tissue. The process is repeated to debulk the lesion in pieces until airway patency is restored.^{64,65}

Tumor coring and debridement (mechanical debulking) is achieved with the rigid biopsy forceps (forceps debridement) or using the beveled edge of the rigid bronchoscope to core and remove tumor fragments from the airway wall (after ensuring tumor coagulation/cryotherapy and devascularization). During the procedure, debris is removed with suction, cryoprobe, or forceps, while bleeding is controlled by bronchoscopic tamponade or APC. Additional procedures performed during rigid bronchoscopy include bronchoscopic dilation or bronchoplasty, and airway stent placement to restore and maintain luminal patency.⁴ This approach is useful for initial tumor debulking and for reducing the FiO_2 , thereby permitting the subsequent safe application of thermal and other ablative techniques. Selection of the specific technique depends on tumor characteristics, anatomic location, degree of airway compromise, and operator expertise.⁴⁸

Foreign Body Removal

Rigid bronchoscopy is the preferred modality for removal of tracheobronchial foreign objects, particularly in⁶⁶:

- Large or sharp objects
- Objects causing critical airway compromise
- Pediatric airway foreign bodies

Adult foreign body aspiration is uncommon, with observational data reporting 0.66 cases per 100,000 and one center retrieving 12 FBs over 2 years. The nature of the inhaled objects is highly variable ranging from organic to inorganic materials.⁶⁷

In adults, acute asphyxiation from large upper airway FBs is uncommon. FB aspiration more often has a subtle or silent presentation, with distal impaction in lower lobe bronchi. Cough is the most frequent symptom, while other manifestations typically reflect complications such as pneumonia, bronchial stenosis, bronchiectasis, fever, hemoptysis, chest pain, or wheeze. Imaging findings depend on the FB's type, location, and duration; since most are radiolucent and missed on plain radiographs (neck and chest), CT is indicated only when suspicion persists, and in adults with delayed presentation imaging often shows complications such as post-obstructive pneumonia or atelectasis rather than the FB itself.^{67,68}

If clinical suspicion remains high for a FB aspiration, irrespective of radiographic imaging, visual airway inspection is recommended as many organic FBs are radiolucent.⁶⁹ Gustav Killian opened the era of bronchoscopy in 1897 when he extracted a pork bone from the trachea of a German farmer using an esophagoscope.¹ The use of rigid versus flexible bronchoscopy has been debated for many years. Flexible bronchoscopy can be used for the diagnosis and extraction of FBs, which may be removed using forceps, snares or baskets (figure 19). It is more accessible and less expensive, and a general anaesthetic is not required.⁶⁷

Rigid bronchoscopy remains the procedure of choice for asphyxiating FBs because it offers superior airway control, suction and extraction capabilities. In life threatening situations of an aspirated FB causing complete upper airway obstruction, secure oxygenation and the airway immediately via bag-mask ventilation and intubation; emergent cricothyrotomy/tracheotomy is needed if supraglottic obstruction prevents ventilation. Inspect the oropharynx promptly, as one-third of asphyxiating FBs may be supraglottic and can be retrieved with Magill forceps. In near-cardiac arrest with complete tracheal obstruction, a "down-then-up maneuver" using an ETT to displace the object into a main bronchus may enable life-saving single-lung ventilation.⁷⁰

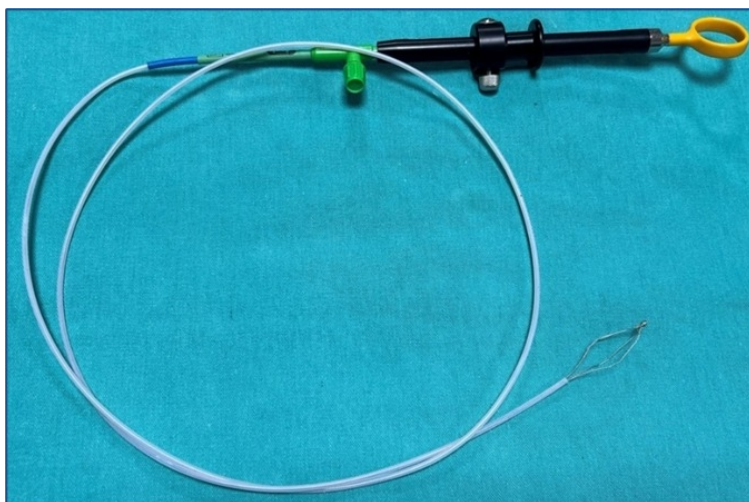


Figure 19. Flexible bronchoscopic foreign body retrieval basket used to grasp and extract foreign bodies, tissue fragments, or clots via a distal wire basket controlled by a proximal handle.

Flexible bronchoscopy is preferred for FBs in distal airways not accessible with the rigid bronchoscope, and for intubated patients or those with cervical instability or facial trauma. In stable, non-emergent patients with suspected FB aspiration, early diagnostic and/or therapeutic flexible bronchoscopy is indicated but should be performed in a setting equipped for resuscitation and advanced airway management, with rigid bronchoscopy readily available, as clinical decompensation may occur from inadvertent FB dislodgement during the procedure.^{67,68} Bronchoscopic visualization is required to confirm the diagnosis of a foreign body. For foreign bodies in the central airways, rigid bronchoscopy is preferred, especially for large, irregular, sharp, or hard objects, or when flexible bronchoscopy is unsuccessful. It secures the airway, maintains ventilation, provides superior visualization, and accommodates large instruments, suction, and a flexible bronchoscope. Many experienced centers use it as the first-line approach, often combined with flexible bronchoscopy.

Successful extraction depends on maintaining a clear field of view, preventing distal migration, grasping the object at its broadest point, and inspecting the airway after removal. Tools used via the rigid scope include large forceps, snares, baskets, and cryoprobes. Alligator forceps are suited for sharp or irregular objects due to their strong grip, while smooth forceps work best for rounded objects, allowing en bloc removal with minimal displacement (figure 20). Regardless of the device, the scope and forceps should be withdrawn together as a single unit to avoid dislodging the object.

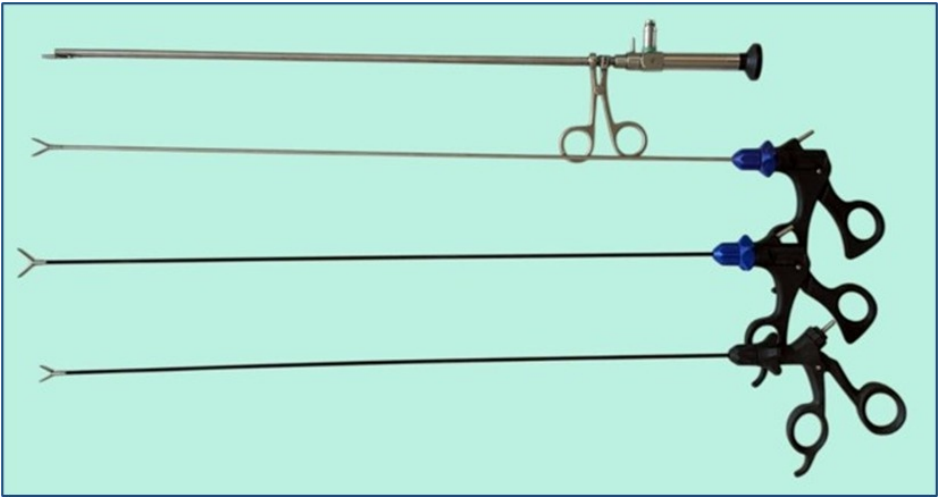


Figure 20. Rigid bronchoscopy FB retrieval forceps set showing top: telescope mounted retrieval forceps, and below: FB grasping forceps with alligator jaw, smooth cup jaw, and rat tooth jaw.

Technique selection is often dictated by the clinical scenario and operator experience, with locally adapted approaches being common (figures 21 and 22). For example, Trendelenburg positioning may be employed during extraction of heavy metallic FBs to reduce the risk of aspiration. If the FB is lost during retrieval, the oral cavity and larynx should be systematically inspected prior to reinsertion of the rigid bronchoscope. It is also important to consider that the FB may be inadvertently swallowed and pass into the stomach during the extraction procedure. Thoracotomy is reserved for rare, recalcitrant cases.

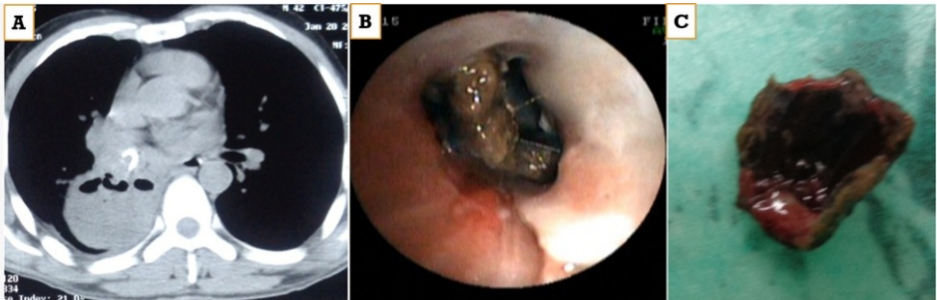


Figure 21. Post-obstructive lung abscess secondary to FB aspiration in a 42-year-old male (A) Chest CT showing a non-resolving consolidation and air trapping with a radiopaque FB obliterating the bronchus (B) Bronchoscopic view reveals an impacted brownish FB within the right lower lobe bronchus (C) Retrieved FB identified as a walnut shell fragment.

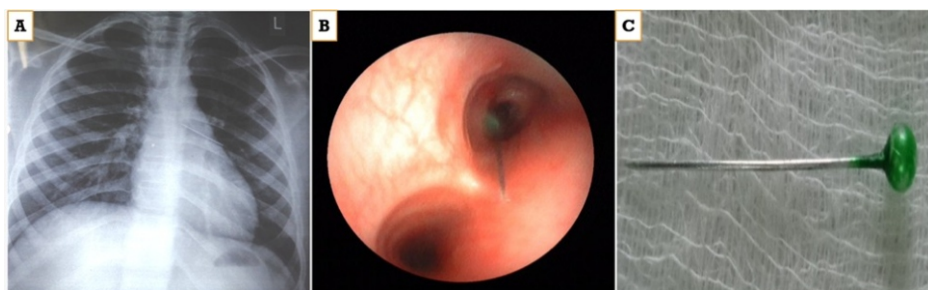


Figure 22. Accidental scarf pin aspiration in a 13-year-old female (A) CXR-PA view demonstrating a linear metallic FB lodged in the left main bronchus (LMB) (B) Bronchoscopic image confirms the scarf pin within the LMB lumen (C) Post-retrieval image showing successful removal of the intact scarf pin.

Removal of Mucus Plugs/Clots

The rigid bronchoscope allows more efficient clearance of blood clots and thick airway secretions compared to flexible bronchoscopy, as its larger diameter accommodates higher-capacity suction devices. Central airway thick mucus plugs or pseudomembranes (figure 23), can cause severe dyspnea and stridor and may necessitate therapeutic rigid bronchoscopy for removal.⁷¹

Cryotherapy (described in bronchoscopic ablative therapies above) plays a targeted role in clearing thick clots and mucus plugs from the airway during bronchoscopy.⁴⁸ The cryoprobe delivers sub-zero temperatures, typically -40°C to -86°C , which rapidly freezes water inside the clot or mucus plug. This forms ice crystals that bind the material to the probe tip through “cryoadhesion.” After a few seconds of freezing, the probe is retracted, pulling the entire frozen clot or mucus plug out in one piece instead of breaking it into fragments.⁶³ This is especially useful for organized blood clots or tenacious mucus plugs that are too sticky or rubbery for suction or forceps alone, since mechanical removal often breaks them and leaves residue and risks bleeding. The freeze also causes local vasoconstriction, reducing bleeding when removing clots, and the tissue underneath remains relatively spared because the cold effect is superficial and controlled.^{48, 63} Because of this, cryotherapy can be used to quickly restore airway patency in patients with hemoptysis, atelectasis, or mucus plugging from asthma, bronchiectasis, or post-infection pseudomembranes.⁷¹

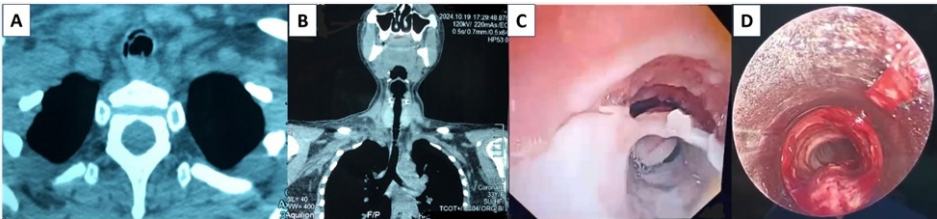


Figure 23. A 33-year-old female developed stridor and respiratory distress 2 days post-extubation following 48-hour mechanical ventilation for eclampsia-complicated cesarean section: (A) Axial CT neck: Soft tissue attenuation membranous lesion adherent to left lateral/posterior tracheal walls (B) Coronal CT neck: 5 cm tracheal luminal abnormality 2 cm below vocal cords to 3 cm above carina (C) Rigid bronchoscopy: Fleshy, whitish Obstructive Fibrous Tracheal Pseudomembrane with cast-like morphology obstructing >80% of lumen (D) Post-removal view: Restored tracheal patency with clear passage.

Management of Massive Hemoptysis

Rigid bronchoscopy plays a critical role in airway stabilization and bleeding control.⁷²

Indications include:

- Direct airway access for suction and clot removal
- Direct tissue tamponade
- Isolation and protection of the non-bleeding lung

Airway hemorrhage can sometimes be rapidly fatal. Mortality risk depends on the volume and rate of hemoptysis, the patient's baseline respiratory function, and comorbid conditions.⁴ In stable patients with minimal hemoptysis, bronchoscopy serves both diagnostic and therapeutic roles by identifying specific causes such as endobronchial tumors, tuberculosis, occult FBs, or mucosal ulceration. For life-threatening hemoptysis, flexible bronchoscopy remains the initial bedside approach to localize bleeding to a particular lung or segment.⁷³

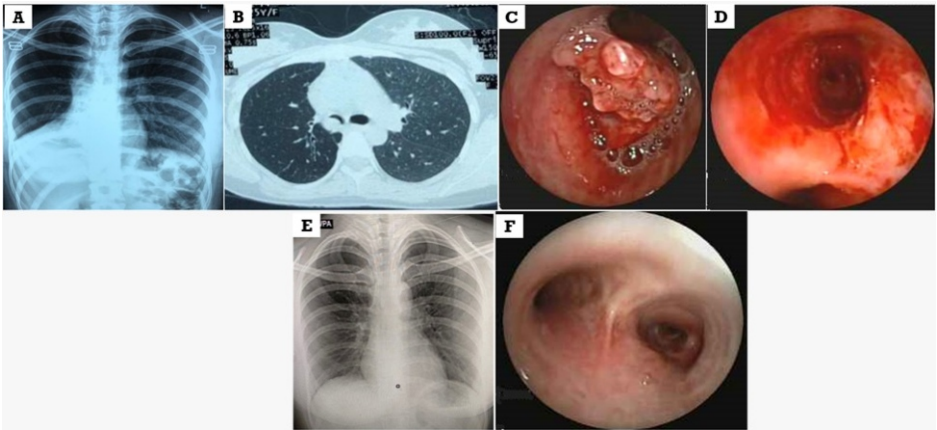


Figure 24. A 25-year-old-female presented with low-grade fever, progressive dyspnea, cough, and intermittent hemoptysis, and diagnostic workup revealed a tumor in the bronchus intermedius causing middle and right lower lobe atelectasis. (A) CXR demonstrating right hemithorax volume loss with collapse of the right lower lobe, characterized by a triangular opacity in the right lower zone, (B) HRCT chest image revealing a tumor in the bronchus intermedius, causing partial narrowing (wink sign), (C) Rigid bronchoscopic view showing tumor obstruction of the bronchus intermedius with patent middle lobe bronchus at 12 o'clock position, (D) Post-tumor debulking bronchoscopic view demonstrating restored bronchial patency (E) follow-up CXR at one year, showing clearance of right lower zone opacity, restored volume in right hemithorax, and clear right hemidiaphragm shadow and (F) One-year follow-up-bronchoscopic-view of the carina, confirming clear bronchus intermedius and patent distal segmental airways without tumor recurrence.

A key limitation of the fiberoptic bronchoscope is its narrow suction channel, which is easily occluded by blood and clots. Endoscopic visualization is often impaired by blood on the lens, and pulmonary ventilation may be inadequate during bleeding.⁴ Many operators favor rigid bronchoscopy for massive hemoptysis because it offers superior suction capacity, direct tamponade capability, and better visualization of large clots and central lesions (figure 24). The wide internal lumen allows clear endoscopic views, controlled ventilation, rapid aspiration of blood and clots, and passage of instruments for selective lung intubation when needed. A therapeutic flexible bronchoscope with a ≥ 2.8 mm working channel is typically passed through the rigid scope, combining distal airway access with large-bore suction and airway control.

After removal of thrombus and blood, careful inspection and segmental lavage help identify active bleeding sites or culprit lesions such as tumors or Dieulafoy disease.⁷⁴

Hemostatic techniques include iced saline, topical epinephrine, balloon tamponade, bronchial blockers, and thermal ablative therapies including laser, electrocautery, APC, or cryotherapy. While balloon or blocker placement requires advanced bronchoscopic skills, ablative interventions demand interventional expertise and are best performed via rigid bronchoscopy given its safety profile for managing major airway bleeding.⁷⁵ Cold saline lavage, APC, laser photocoagulation, and electrocautery achieve 85–100% success rates and can be used to manage airway lesions causing bleeding and hemoptysis.⁷⁶

Benign Central Airway Obstruction (Airway Stenosis Dilation)

Rigid bronchoscopy is recommended for non-malignant airway narrowing or obstruction where durable airway patency is required.^{77,78}

Indications and interventions include:

- Mechanical airway dilation
- Balloon bronchoplasty
- Heat ablative therapies or cryotherapy for benign lesions
- Airway stent placement, especially silicone stents

Acquired benign tracheal stenosis most commonly results from prolonged endotracheal intubation and post-tracheostomy changes (figure 26). Less frequent causes include prior upper airway surgery, inhalational injury, laryngo-tracheal TB and autoimmune conditions such as sarcoidosis, granulomatosis with polyangiitis, and systemic lupus erythematosus.⁷⁹

Although surgical resection can be curative in selected patients, it does not consistently produce superior outcomes, making endoscopic management a primary option for many cases. Tracheal stenoses are classified as simple or complex according to the degree of airway wall involvement.⁸⁰

Simple tracheal stenoses are limited to the mucosal layer with preserved cartilage integrity. Treatment typically involves radial electrocautery incisions followed by sequential dilation using CRE balloon catheters or the rigid bronchoscope barrel, which can be applied directly to the stenosis, including subglottic lesions (figures 25 and 26). Balloons and bougies may also be introduced through the rigid bronchoscope as needed. Balloon dilation is typically performed using balloons filled with sterile saline or air, which are positioned at the stenotic area and held in place for 30 to 60 seconds at a time to gradually widen the airway.

Complex tracheal stenoses, by contrast, involve cartilage injury, malacia, or instability. These lesions generally require radial electrocautery incisions, rigid bronchoscopic dilation, and stenting to ensure sustained airway patency.⁸¹

The principal advantage of rigid bronchoscopy is the ability to maintain a secure airway with continuous ventilation, which is not feasible during balloon or bougie dilation performed via flexible bronchoscopy.

Rigid bronchoscopy offers immediate symptom relief and enables the application of multiple therapeutic modalities under controlled ventilation. This makes it safer for managing proximal and critical airway lesions.

Stenoses located at the main bronchi, such as those following sleeve lobectomy or transplantation, tend to be tighter and may require initial dilation with balloon catheters or pediatric rigid scopes. Adjunctive techniques including APC, cryotherapy, and balloon bronchoplasty can be used alone or in combination depending on lesion characteristics and operator experience.⁸¹ Outcomes depend on stenosis type. Simple stenoses without cartilage damage often resolve after two to three dilations without the need for stenting. Complex stenoses are more likely to require stenting to maintain long-term patency.⁸² For complex nonmalignant strictures involving two or more tracheal rings with cartilaginous distortion, malacia, or collapse, such as in granulomatosis with polyangiitis, post-tuberculosis stenosis, or severe tracheobronchomalacia, personalized three-dimensional silicone stents may be required for prolonged use beyond three months.^{83,84} Studies using combined endoscopic modalities have demonstrated sustained symptomatic resolution in selected patients. Technique selection should therefore be guided by stenosis type, physician experience, and available equipment.

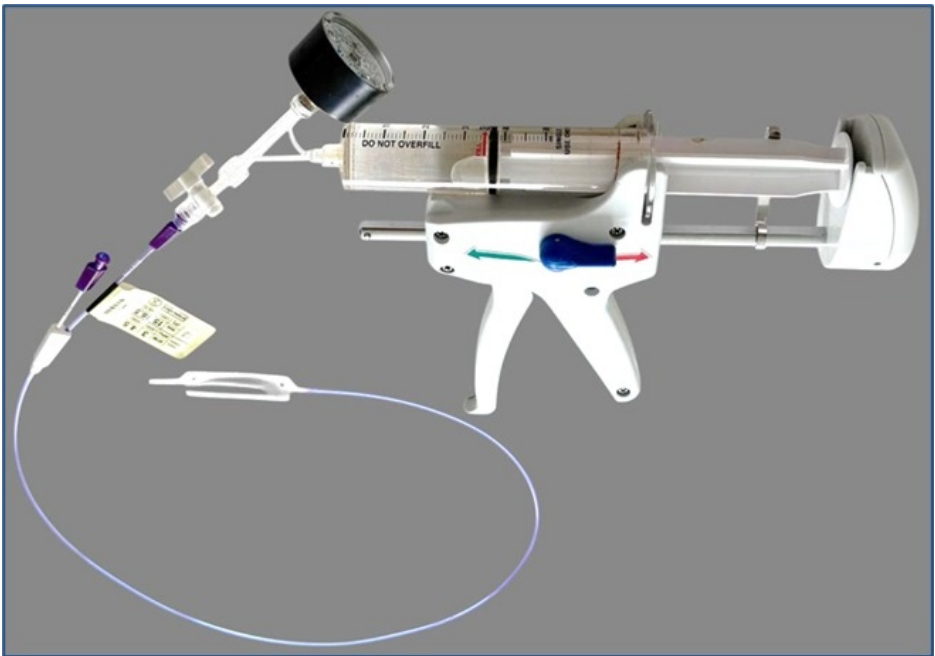


Figure 25. Bronchoscopy CRE balloon inflation device with pistol-grip syringe, pressure gauge, and connected balloon catheter for airway stenosis dilation.

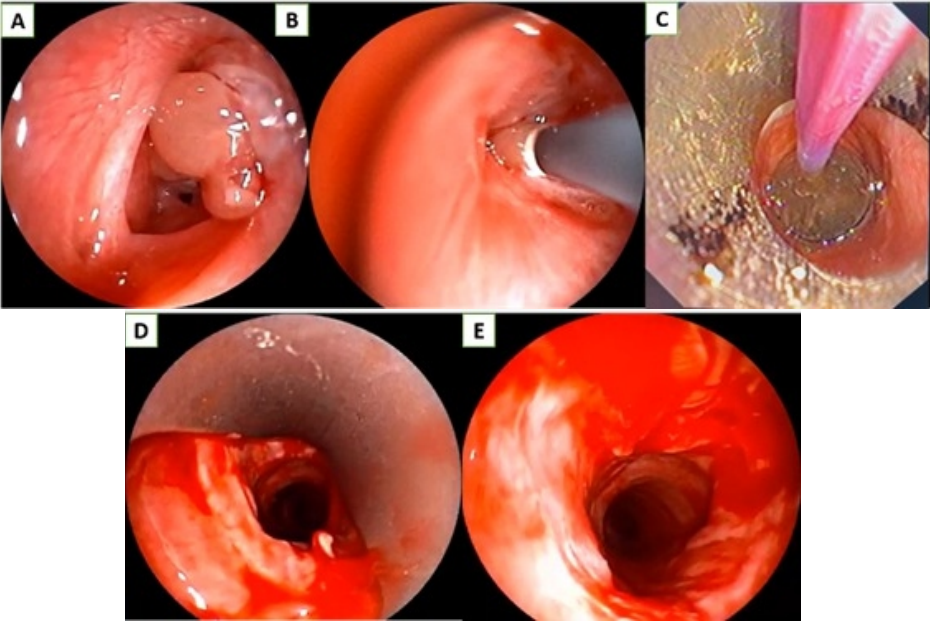


Figure 26. Stepwise endoscopic management of post-tracheostomy tracheal stenosis. (A) Granulation tissue above the tracheostomy site visualized via the larynx (B) Cryotherapy applied to debulk granulation tissue (C) Balloon dilatation of the stenotic segment (D) Rigid bronchoscope barrel dilatation for further lumen expansion (E) Patent airway immediately post-procedure.

Airway Stenting

Airway stents are hollow, tubular devices inserted into the airway for the management of various large airway disorders. They are available in multiple materials, sizes, shapes, and diameters. The three principal categories include silicone stents, metallic stents (covered or uncovered), and hybrid stents consisting of a metal framework coated with silicone, polypropylene, or other materials. Airway stenting serves primarily as palliative therapy or as a bridge to definitive treatment for various airway disorders, most commonly malignant CAO, but also nonmalignant CAO (post intubation/traheostomy tracheal stenosis, inflammatory tuberculous bronchial stenosis etc), tracheo- or bronchoesophageal fistulas, tracheobronchomalacia, and anastomotic dehiscence following lung transplantation.^{42,85}

Successful airway stent placement typically produces immediate relief of symptoms such as dyspnea, cough, and respiratory insufficiency, along with improvements in pulmonary function, exercise capacity, and quality of life.⁸⁶ Prior to placement, comprehensive lesion assessment is required using both bronchoscopy and chest CT with axial, coronal, and sagittal reconstructions. Critical measurements include distance from the vocal cords, lesion length, morphology, luminal diameter, and patency of proximal and distal airways. This preoperative planning determines appropriate stent dimensions and type.⁸⁷

Ideally, centers should stock a wide range of stents to allow individualized selection. In Pakistan, however, stents are not yet routinely available. As more operators start performing these procedures, availability is expected to improve. The choice of stent type and size depends on lesion characteristics and location, anticipated duration, patient preference, cost, and available expertise. First introduced in the mid-1980s, **silicone stents** remain a commonly used, durable option for airway support, offering strong resistance to external compression and material fatigue, and come in various tracheal and bronchial sizes and shapes such as straight, hourglass, Y-shaped/bifurcation, T-tube, J-shaped, conical, and custom configurations. They have lower rates of granulation tissue and tumor ingrowth compared with uncovered metal stents, allowing long-term use beyond 500 days. They are easily repositioned or removed with rigid forceps and are more cost-effective than metallic or hybrid stents. Disadvantages of silicone stents relative to uncovered metal stents include higher rates of migration and infection, greater inhibition of mucociliary clearance with increased risk of mucus plugging, and the typical need for rigid bronchoscopy and general anesthesia for deployment and removal.²⁵

Uncovered **self-expanding metal stents (SEMS)** are tubular mesh prostheses now rarely used due to an FDA boxed warning citing complications including granulation tissue ingrowth and difficult removal, limiting their long-term use in nonmalignant conditions.⁸⁸

Hybrid stents combine metal frames for radial strength with silicone coverings to limit tumor and granulation ingrowth, addressing drawbacks of pure silicone or metal stents. They are costlier but often have loops for repositioning and may be placed via rigid or flexible bronchoscopy. Designs include silicone-covered metal stents that retain expansile force but are hard to remove, nitinol shape-memory stents that conform well but migrate more, and Y-shaped dynamic stents that mimic tracheal anatomy for long strictures or

tracheobronchomalacia. Partially covered variants allow ventilation of jailed bronchi, though epithelialization at uncovered ends can complicate extraction.^{89,90}

For malignant central airway stenosis, silicone stents are appropriate for long-term palliation, whereas covered SEMS are reasonable when short-term relief of approximately 6 to 12 weeks is expected. Median survival after stenting for malignant obstruction is often limited to 4–5 months, underscoring the palliative intent of SEMS in this setting. In benign tracheoesophageal fistulas, silicone stents are preferred for prolonged use because they can be removed, while covered SEMS may be used for short-term palliation of malignant fistulas. In tracheobronchomalacia, silicone Y-stents are used both as a diagnostic trial to predict response to surgical tracheoplasty and for long-term symptom control when surgery is not feasible. Y-shaped stents are also indicated for disease involving the lower trachea and carina.

Airway stents are typically placed bronchoscopically under direct visualization. Silicone stents require rigid bronchoscopy with general anesthesia, while self-expanding metal stents can be deployed using flexible bronchoscopy with moderate sedation. Stent insertion may be performed during the same bronchoscopic intervention as other procedures such as dilation, cryosurgery, electrosurgery, or laser resection, or it may be done later as a palliative measure if the lesion recurs. For benign stenotic lesions not suitable for resection, airway dilation should be performed prior to silicone stent placement.⁹¹

Each stent is unique and requires specific manufacturer instructions for deployment. **Deployment technique** varies by stent type and may be done with or without fluoroscopic guidance. Some silicone stents are placed using rigid bronchoscopic grasping forceps, while others require manufacturer-specific deployment systems. Silicone stents generally require preliminary airway dilation, whereas SEMS dilate the stenosis during expansion. Stents are usually deployed directly into the stricture, though in some cases the stent is positioned distal to the stricture and then pulled proximally to ensure adequate coverage of both margins. In patients with obstructive lesions, identifying the critically narrowed “choke point” can be challenging during bronchoscopy.⁹²

Multimodality assessment with spirometry, ultrathin bronchoscopy, and endobronchial ultrasound may help guide stent placement at the choke point, but this approach is technically demanding and remains experimental. The choke point may also shift after stent placement, potentially requiring revision or placement of an additional stent.⁹³ Most stents are supplied with a dedicated deployment system that facilitates accurate positioning in cases of stenosis or malignant tracheoesophageal fistula.⁴⁸ As an example, Dumon® silicone stent insertion using the Novatech Tonn Set (figure 27) is performed via rigid bronchoscopy under general anesthesia.



Figure 27. Tonn-Applicator system (Novatech®) for Dumon silicone stent deployment, arranged top to bottom:

1. **Basic block with folding device and clamping rod: housing for the stent prior to deployment.**
2. **Pusher and introducer tube: main instrument with thumb-ring handle for stent advancement.**
3. **Loading rod: Used to load the stent into the applicator and assist positioning.**
4. **Stent grasping forceps - for intraprocedural manipulation and adjustment of the stent.**
5. **Dumon silicone stents - unmounted stents ready for loading and deployment.**

NOVATECH Stent Applicator:

[<https://novatech.fr/en/tracheal/bronchial-stents/dumon-stents/original-dumon>]

[Youtube Video: <https://www.youtube.com/watch?v=5BYyE6f9lpw>]

After measuring the stricture and selecting a stent 1-2 mm larger in diameter with planned margins of 5-10 mm beyond both the proximal and distal ends of the lesion, the stent is folded and loaded into the lubricated introducer tube of the Tonn Set. Once any necessary pre-dilation is completed, the rigid bronchoscope is positioned just proximal to the stenosis and the loaded introducer is advanced through the barrel until its distal tip lies beyond the distal end of the lesion. The stent is deployed by holding the pusher stationary while withdrawing the outer introducer sheath, allowing it to re-expand so that it spans the entire lesion with the proximal end positioned 5-10 mm above the upper margin of the stricture and the distal end extending 5-10 mm below the lower margin. Position is fine-tuned with rigid grasping forceps to ensure complete coverage of the stenosis while avoiding unintentional obstruction of adjacent lobar or segmental airways. The delivery system is then withdrawn and final stent position, expansion, and airway patency are confirmed bronchoscopically.^{13,42}

While most patients tolerate airway stents well at first, up to one-third develop complications, though life-threatening problems are uncommon. These complications can include granulomatous tissue or tumor ingrowth above, below, or through the stent, reduced mucociliary clearance, stent migration, and recurrent infection. Less commonly, patients

may experience airway perforation, stent fracture, metal fatigue, or fistula formation involving nearby vascular or nonvascular structures.^{94,95}

Following airway stent placement, monitor patients clinically for symptom relief, including improvement in dyspnea (figures 28 and 29). Bronchoscopy should be performed if new respiratory symptoms arise to assess for stent-related complications.⁹⁶ Stents should be removed if no longer needed or causing major complications. Silicone stents are easier to remove than metal ones, usually with rigid bronchoscopy using a twist-and-pull technique. Metal stent removal is difficult after 6 weeks and has high complication rates, including reobstruction and respiratory failure. Remove the stent in one piece when possible, and clear granulation tissue first while avoiding ablative techniques that risk airway fire. Some stents have proximal sutures to aid removal, and dilation may be needed to free embedded metal stents.⁹⁶

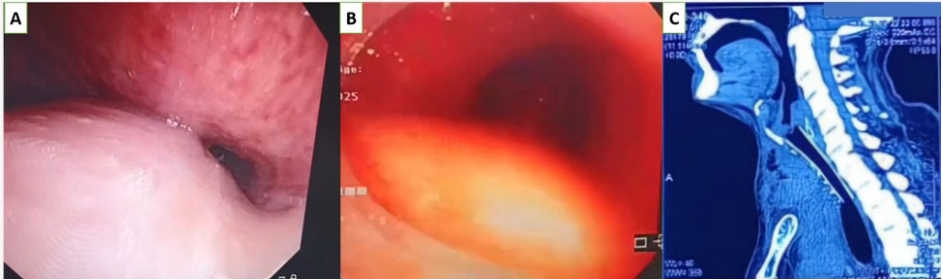


Figure 28. Palliative rigid bronchoscopy with balloon dilation and silicone stent placement for malignant tracheal compression from invasive thyroid carcinoma in a 65-year-old male:

- A. Bronchoscopic view of severe upper tracheal external compression with patent channels around the margins.**
- B. Restored airway patency following silicone stent placement.**
- C. CT neck confirming silicone tracheal stent in situ with maintained lumen patency.**

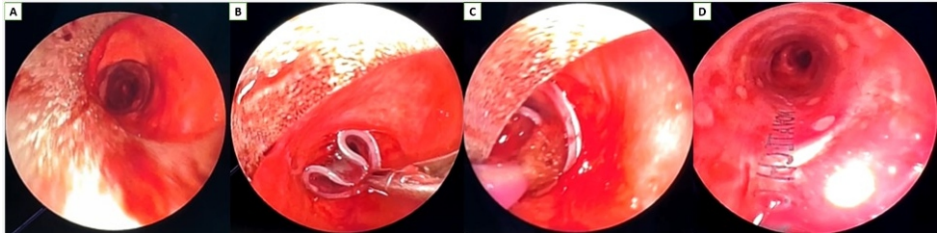


Figure 29. Rigid bronchoscopy for recurrent post-intubation tracheal stenosis with silicone stent placement:

- A. Bronchoscopic view of subglottic stenosis 3 cm below the vocal cords following CRE balloon and rigid dilation.**
- B. Deployment of a 16/80 mm Dumon silicone stent using Tonn-set stent delivery system and positioning with rigid forceps.**
- C. Stent expansion achieved with CRE balloon inflation within the lumen.**
- D. Final view through the expanded stent demonstrating a patent airway and visible carina distally.**

Large Diagnostic Tissue Biopsy

Biopsy specimens obtained via rigid bronchoscopy are typically larger than those acquired with flexible bronchoscopy, since the forceps used through a rigid scope have a greater diameter and can obtain more substantial tissue samples, improving diagnostic accuracy. This is particularly important for tumors such as carcinoids, which require large biopsies for definitive diagnosis. In addition, rigid bronchoscopy allows effective management of bleeding if it occurs during the procedure.

Rigid bronchoscopy is indicated when.^{6,97}

- Large endobronchial tissue samples are required
- Flexible bronchoscopy is inadequate or unsafe
- Significant bleeding risk is anticipated

Percutaneous Tracheostomy Placement

The rigid bronchoscope is occasionally used to stabilize the airway and provide guidance during percutaneous tracheostomy placement in complex patients, such as those with coagulopathy.⁹⁸

Miscellaneous Procedures

Beyond standard debulking and stent placement, rigid bronchoscopy facilitates a range of miscellaneous therapeutic and diagnostic procedures. It is used for the deployment of endobronchial valves and coils and for assessing collateral ventilation in patients with emphysema. The rigid platform is also valuable in managing complex bronchial complications following lung transplantation. Furthermore, it can be combined with advanced techniques such as radial endobronchial ultrasound, electromagnetic navigation bronchoscopy, and transbronchial cryobiopsy to enhance diagnostic yield and procedural safety. For symptomatic malignant central airway obstruction, current guidelines recommend therapeutic bronchoscopy as an adjunct to systemic therapy and/or radiotherapy.⁴⁸

Table 3. Indications and clinical uses of rigid bronchoscopy for therapeutic and diagnostic airway management.

Indication Category	Specific Indications / Uses	Key Notes / Rationale
Therapeutic Management of Central Airway Obstruction	<ul style="list-style-type: none"> -Malignant CAO: palliation/restoration of airway patency in primary or metastatic malignancies -Benign CAO: benign tracheal stenosis, tracheomalacia, post-intubation/tracheostomy stenosis -Mixed obstruction: endoluminal tumor + extrinsic compression 	Preferred when flexible bronchoscopy is insufficient. Rapidly secures airway in respiratory failure. Improves performance status, QoL, and physiology in malignant CAO
Tumor Debulking & Recanalization	<ul style="list-style-type: none"> -Mechanical debridement/core debulking with rigid scope -Forceps debulking -Thermal ablation: APC, electrocautery, laser -Cryotherapy/cryodebridement -Microdebrider-assisted removal 	Recommended if distal airway and pulmonary artery are patent. Safe/successful in up to 83% of central airway tumors
Foreign Body Removal	<ul style="list-style-type: none"> -Large or sharp objects -Objects causing critical airway compromise -Pediatric airway foreign bodies -FBs not amenable to flexible bronchoscopy 	Preferred for asphyxiating FBs due to superior airway control, suction, and extraction. En bloc removal with scope recommended
Management of Massive Hemoptysis	<ul style="list-style-type: none"> -Direct suction and clot removal -Direct tissue tamponade -Isolation/protection of non-bleeding lung 	Offers superior suction, tamponade, and visualization vs flexible scope. Allows passage of therapeutic flexible scope through rigid barrel
Airway Stenosis Dilatation & Bronchoplasty	<ul style="list-style-type: none"> -Mechanical dilatation with rigid barrel -Balloon bronchoplasty -Heat ablation/cryotherapy for benign lesions 	Maintains secure airway/ventilation during dilatation. Simple stenoses often resolve after 2-3 dilations
Airway Stent Placement	<ul style="list-style-type: none"> -Silicone stents for malignant and benign CAO -Metallic/hybrid stents for malignant CAO, fistulas, tracheobronchomalacia -Y-stents for lower trachea/carina disease 	Provides immediate symptom relief and improved spirogram Silicone stents preferred for long-term benign disease
Mucus Plug/Clot Removal	Removal of thick mucus plugs, blood clots, fibrinous pseudomembranes	Larger diameter allows high-capacity suction vs flexible bronchoscopy
Large Diagnostic Tissue Biopsy	Obtaining large endobronchial samples for diagnosis, especially carcinoid tumors	Larger forceps via rigid scope improve diagnostic yield. Safer if bleeding risk anticipated
Percutaneous Tracheostomy	Airway stabilization and guidance during percutaneous dilatational tracheostomy in complex patients	Useful rarely in coagulopathy and difficult anatomy
Miscellaneous Procedures	<ul style="list-style-type: none"> -Deployment of endobronchial valves/coils -Management of post-transplant bronchial complications -Combined with EBUS, ENB, transbronchial Cryobiopsy 	Rigid platform supports advanced interventional techniques

Complications of Rigid Bronchoscopy

Complication rates are low, with fewer than 4% of cases affected and most being mild. The majority are associated with intubation, anesthesia, or ancillary procedures. However, compared to endotracheal intubation and flexible bronchoscopy, rigid bronchoscopy carries a greater risk of airway laceration and perforation.^{25,77}

Incidence and Risk Profile

- Overall complication rates range from 3.9% to 13.4% across reported series.
- Overall procedure-related mortality is <1%.
- Increased risk of complications is associated with:
 - Use of moderate sedation instead of general anesthesia
 - American Society of Anesthesiologists Physical Status (ASA) physical status > III
 - Repeat (re-do) rigid bronchoscopy procedures

Appropriate patient selection, team training, and operator expertise are critical to minimizing complications.

Minor Complications

- Sore throat (most common)
- Minor mucosal irritation

Upper Airway and Oropharyngeal Complications

- Lip and dental trauma (including tooth dislodgement)
- Oropharyngeal mucosal injury

These are commonly related to poor intubation technique or inadequate preprocedural airway and dental assessment.

Laryngeal and Vocal Cord Injury

- Laryngeal edema
- Injury to arytenoids
- Vocal cord trauma

These may occur during passage through the larynx and require gentle technique and adequate visualization.

Cervical Spine and Musculoskeletal Complications

- Cervical spine injury or paralysis due to neck hyperextension

High-risk patients include those with cervical stenosis, unstable cervical spine, severe osteoporosis, or limited neck mobility.

Airway Trauma and Structural Injury

- Tracheobronchial laceration or perforation

Possible consequences include pneumothorax, pneumomediastinum, and bronchovascular fistulae. Continuous visualization of the distal beveled end of the rigid bronchoscope is essential to minimize risk.

Intra-procedural and Adjunct-related Complications

- Bronchospasm
- Airway bleeding
- Procedure-related airway trauma
- Complications related to thermal, mechanical, or cryo-ablative tools

Anesthesia and Shared Airway Complications

- Hypoxemia
- Hypercapnia

Continuous communication between the bronchoscopist and anesthesiologist is essential due to the shared airway.

Major Systemic Complications

Rare but serious risks include respiratory failure, myocardial infarction, cerebrovascular accident, and death. Peri-procedural mortality is reported to be <1%, though it varies with the indication, the patient's overall condition and comorbidities, procedural urgency, whether the procedure is diagnostic or therapeutic, stent use, and the operator's experience.²⁵

Precautions, Contraindications, and Caveats

Absolute Contraindications

Although rigid bronchoscopy has few absolute contraindications, the proceduralist must carefully evaluate patients prior to the procedure.^{24,46} Absolute contraindications include:

- Unstable facial fractures
- Congenital or acquired facial malformations
- Severe laryngeal disease or upper airway obstruction preventing passage of rigid instruments
- Cervical spine instability (e.g., trauma, rheumatoid arthritis)
- Prior cervical spine fusion
- Severe cervical spondylosis
- Markedly limited cervical spine mobility precluding safe neck hyperextension required for rigid intubation

Relative Contraindications and Clinical Precautions

Rigid bronchoscopy is most often performed for therapeutic indications in a vulnerable patient population. Therefore, careful risk–benefit assessment is essential. Clinical considerations include:

- Risk of respiratory failure related to rigid bronchoscopy and general anesthesia
- Underlying cardiovascular disease and perioperative cardiac risk
- Presence of coagulopathy or bleeding diathesis
- Overall physiologic reserve and predictors of therapeutic success

The anticipated benefits of intervention should clearly outweigh procedural and anesthetic risks before proceeding.

Procedural Caveats

- Rigid bronchoscopy should be performed only by trained and experienced teams in appropriately equipped centers
- Pre-procedural planning must include airway assessment, cervical spine evaluation, and anesthesia coordination
- Alternative diagnostic or therapeutic approaches should be considered when risks outweigh expected benefit

Rigid Bronchoscopy Training Requirements

International recommendations including NICE guideline CG121 states that all cancer centers should provide rapid access to a team capable of performing interventional endobronchial treatments, and the advantages of rigid bronchoscopy are outlined in the BTS guideline on therapeutic procedures.⁵⁶ A recent ACCP publication sets accreditation standards for IP fellowships in the USA, outlining a 12-month curriculum, required case volumes, and cross-specialty exposure to strengthen IP as a respiratory subspecialty.⁹⁹ Compared to the US and Europe, only a few centers in Pakistan currently offer interventional pulmonology training that includes rigid bronchoscopy. However, these practices are growing and are expected to become more common over time. Rigid bronchoscopy training is typically reserved to physicians who already have substantial experience with flexible bronchoscopy and endotracheal intubation. Trainees begin with practice on mannequins or animal models before progressing to at least 20 supervised rigid bronchoscopy procedures. To maintain competency, physicians should perform 10 to 15 procedures per year.⁴²

Limitations of Rigid Bronchoscopy

Rigid bronchoscopy requires general anesthesia, an experienced operator, and careful technique to minimize the risk of iatrogenic injury. It is typically performed in operating theatres, where scheduling delays can occur due to competition with surgical cases for available time slots. Moreover, its primary application is limited to the central airways, making access to peripheral and upper lobe lesions, particularly in the right upper lobe, challenging. In complex cases, introducing a flexible bronchoscope through the rigid scope can extend access to upper lobe lesions and improve therapeutic reach. Training opportunities for rigid bronchoscopy are also limited to a small number of specialized centers. Proficiency typically requires 20–25 procedures, and outcomes depend on both the operator's skill and a coordinated, experienced team.

Future Directions

Rigid bronchoscopy is evolving through the integration of robotics and artificial intelligence (AI). Robotic tools fitted inside the rigid scope are enabling precise interventions in peripheral airway lesions, with expanding use for diagnosis, needle-based therapy, and management of airway stenosis, tracheomalacia, and surgical complications. The technology also supports natural orifice surgical approaches. AI is expected to improve procedural safety by optimizing navigation and patient positioning to reduce periprocedural injury.^{100,101}

Conclusion

Rigid bronchoscopy continues to be a core therapeutic modality in interventional pulmonology for the management of central airway obstruction and related pathologies. In centers with trained bronchoscopists, appropriate anesthesia support, and adequate equipment, the procedure provides effective airway recanalization with a favorable safety profile. Optimal clinical outcomes in the Pakistani context are contingent upon standardized procedural technique, adherence to safety protocols, availability of essential instrumentation and stents, and coordinated multidisciplinary care involving pulmonology, anesthesia, and thoracic surgery teams.

References

1. Killian G. Über directe Bronchoscopie. *MMW* 1898;27:844–7
2. Becker HD. The history of rigid bronchoscope. In: Ernst A and Herth JF ed. "Principles and Practice of Interventional Pulmonology". Springer New York 2013, pp. 3–13.
3. Ikeda S, Yanai N, Ishikawa S. Flexible bronchofiberscope. *Keio Journal of Medicine* 1968; 17: 1–16.
4. Dutau H. Rigid Bronchoscopy and Endobronchial Tumor Ablation. In: Musani A, Dalar L, editors. *WABIP textbook of Interventional Pulmonology*. 2025.
5. Gordon J. Rigid bronchoscopy. In: Ernst A, Herth FJF, eds. *Principles and Practice of Interventional Pulmonology*. New York: Springer Science+Business Media, 2013; pp. 285–296.
6. Athanassiadi K, Na KJ, Zanowska K, Costa R, Zairi S, Cardillo G et al. The utility of a rigid bronchoscope. *Breathe (Sheff)*. 2025 Nov 18;21(4):240252.
7. Hussain G, Iqbal M, Khan SA, Iqbal M, Zaman J. An experience of 42 cases of bronchoscopy at Saidu Group of Teaching Hospitals, Swat. *J Ayub Med Coll Abbottabad*. 2006 Jul-Sep;18(3):59–62.
8. Dutau H. Rigid Bronchoscopy. *Pak J Chest Med*. 2012;18(1):1–8.
9. Mahmud T. Revival of the Rigid Bronchoscopy. *Pakistan Chest Society*. PCS Chestcon Karachi; 2021 Dec 5.
10. Broaddus VC, Mason RJ, Ernst JD, editors. *Murray & Nadel's Textbook of Respiratory Medicine*. 7th ed. Philadelphia: Elsevier; 2022.
11. Grippi MA, Elias JA, Fishman JA, editors. *Fishman's Pulmonary Diseases and Disorders*. 5th ed. New York: McGraw-Hill Education; 2015.
12. Ernst A, Herth FJF, editors. *Principles and Practice of Interventional Pulmonology*. New York: Springer; 2013.
13. Ernst A, Feller-Kopman D, Becker HD, Mehta AC. Central airway obstruction. *Am J Respir Crit Care Med*. 2004;169(12):1278–97.
14. Standring S, editor. *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. 42nd ed. London: Elsevier; 2020.
15. West JB, Luks AM. *West's Respiratory Physiology: The Essentials*. 11th ed. Philadelphia: Wolters Kluwer; 2021.
16. Colt HG, Harrell JH, Crawford SW. Neoplastic airway obstruction. *Clin Chest Med*. 1995;16(3):465–478.
17. Mehta AC, Jain P, Gildea TR. Airway stenosis and bronchoscopic management. *Proc Am Thorac Soc*. 2008;5(4):356–362.
18. Freitag L, Ernst A, Unger M, Kovitz K, Marquette CH. A proposed classification system of central airway stenosis. *Eur Respir J*. 2007;30(1):7–12.
19. Murgu SD, Colt HG. Tracheobronchomalacia and excessive dynamic airway collapse. *Respirology*. 2006;11(4):388–406.
20. Putz L, Mayne A, Dincq AS. Jet Ventilation during Rigid Bronchoscopy in Adults: A Focused Review. *Biomed Res Int*. 2016;2016:4234861.
21. Batra H, Yarmus L. Indications and complications of rigid bronchoscopy. *Expert Rev Respir Med*. 2018;12:509–20.
22. de Lima A, Kheir F, Majid A, Pawlowski J. Anesthesia for interventional pulmonology procedures: a review of advanced diagnostic and therapeutic bronchoscopy. *Can J Anaesth*.

2018;65:822-36.

23.Dincq AS, Gourdin M, Collard E, Ocak S, D'Odemont JP, Dahlqvist C, et al. Anesthesia for adult rigid bronchoscopy. *Acta Anaesthesiol Belg.* 2014;65:95-103.

24.Pathak V, Welsby I, Mahmood K, Wahidi M, MacIntyre N, Shofer S. Ventilation and anesthetic approaches for rigid bronchoscopy. *Ann Am Thorac Soc.* 2014;11:628-34.

25.Ost DE, Ernst A, Grosu HB, Lei X, Diaz-Mendoza J, Slade M, et al. Complications Following Therapeutic Bronchoscopy for Malignant Central Airway Obstruction: Results of the AQUIRE Registry. *Chest.* 2015;148:450-71.

26.Fernandez-Bustamante A, Ibanez V, Alfaro JJ, de Miguel E, German MJ, Mayo A, et al. High-frequency jet ventilation in interventional bronchoscopy: factors with predictive value on high-frequency jet ventilation complications. *J Clin Anesth.* 2006;18:349-56.

27.Chumpathong S, Tscheikuna J, Boonsombat T, Muangman S, Luansritisakul C. Incidence and Risk Factors of Hypoxemia During Interventional Rigid Bronchoscopy Under Spontaneous-assisted Ventilation. *J Bronchology Interv Pulmonol.* 2017;24:268-74.

28.Murgu S, Laxmanan B, Stoy S, Egressy K, Chaddha U, Farooqui F, et al. Evaluation of Safety and Short-term Outcomes of Therapeutic Rigid Bronchoscopy Using Total Intravenous Anesthesia and Spontaneous Assisted Ventilation. *Respiration.* 2020;99:239-47.

29.Li JJ, Li N, Ma WJ, Bao MX, Chen ZY, Ding ZN. Safety application of muscle relaxants and the traditional low-frequency ventilation during the flexible or rigid bronchoscopy in patients with central airway obstruction: a retrospective observational study. *BMC Anesthesiol.* 2021;21:106.

30.Frasca L, Sarubbi A, Longo F, Costa F, Sarubbi D, Strumia A, et al. Remifentanil-Propofol-Ketamine- Based Total Intravenous Anesthesia with Spontaneous Breathing for Adult Rigid Bronchoscopy. *J Clin Med.* 2025;14.

31.Tacchi G, Frasca L, Longo F, Sarubbi A, Marziali V, Suriano I, et al. Ketamine administration for rigid bronchoscopy in adult: literary review and the operator perception. *J Thorac Dis.* 2025;17:2655-61.

32.Ghezel-Ahmadi V, Ghezel-Ahmadi D, Mangen J, Bolukbas S, Welker A, Kuerschner VC, et al. Comparing Patient Satisfaction and Intubating Conditions Using Succinylcholine or Low-Dose Rocuronium for Rigid Bronchoscopy: A Randomized Study. *Thorac Cardiovasc Surg.* 2015;63:526-32.

33.Okamoto S, Somiya N, A MS, Kada A, Oki M, Saka H, Tomita A. A Prospective, Randomized Trial Comparing Respiratory Status During Anesthesia for Airway Stenting: Spontaneous Respiration Versus Controlled Ventilation With Muscle Relaxants. *Anesth Analg.* 2020;131:893-900.

34.Vorasubin N, Vira D, Jamal N, Chhetri DK. Airway management and endoscopic treatment of subglottic and tracheal stenosis: the laryngeal mask airway technique. *Ann Otol Rhinol Laryngol.* 2014;123:293-8.

35.Keil O, Huzhva Y, Rigerink V, Dennhardt N, Boethig D, Nickel K, et al. Rigid and Flexible Bronchoscopy for Foreign Body Removal in Children: Complications, Risk Factors and Anesthetic Management. *Pediatr Pulmonol.* 2025;60:e71261.

36.Liu Y, Chen L, Li S. Controlled ventilation or spontaneous respiration in anesthesia for tracheobronchial foreign body removal: a meta-analysis. *Paediatr Anaesth.* 2014;24:1023-30.

37.Cheng Q, Zhang J, Wang H, Zhang R, Yue Y, Li L. Effect of Acute Hypercapnia on Outcomes

and Predictive Risk Factors for Complications among Patients Receiving Bronchoscopic Interventions under General Anesthesia. *PLoS One*. 2015;10:e0130771.

38. Chaddha U, Murgu S. Complications of rigid bronchoscopy. *Respirology*. 2021;26:14-8.

39. Matus I, Wilton S, Ho E, et al. Current Practices Supporting Rigid Bronchoscopy-An International Survey. *J Bronchology Interv Pulmonol* 2023; 30:328.

40. Kim SH, Chang B, Ahn HJ, et al. Safety of Rigid Bronchoscopy for Therapeutic Intervention at the Intensive Care Unit Bedside. *Medicina (Kaunas)* 2022; 58.

41. Practice Guidelines for Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration: Application to Healthy Patients Undergoing Elective Procedures: An Updated Report by the American Society of Anesthesiologists Task Force on Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration. *Anesthesiology* 2017; 126:376.

42. Bolliger CT, Mathur PN, Beamis JF, Becker HD, Cavaliere S, Colt H, et al. ERS/ATS statement on interventional pulmonology. *European Respiratory Society/American Thoracic Society. Eur Respir J*. 2002 Feb;19(2):356-73.

43. Roh JL, Hong SJ. Lung recovery after rigid bronchoscopic removal of tracheobronchial foreign bodies in children. *Int J Pediatr Otorhinolaryngol*. 2008 May;72(5):635-41.

44. Bartlett-Pestell S, May J, Sharma A, Alonzo S, Barnes N, Madden BP. A 12-year experience in endobronchial intervention using rigid bronchoscopy - account of a tertiary referral centre. *Monaldi Arch Chest Dis*. 2022 Mar 24;92(4).

45. Murao H, Oki M, Torii A, Saka H. Rigid bronchoscopic intervention for airway stenosis in post-pneumonectomy patients. *BMC Pulm Med*. 2026 Jan 6;26(1):51. doi: 10.1186/s12890-025-04092-z.

46. Dutau H, Vandemoortele T, Breen DP. Rigid bronchoscopy. *Clin Chest Med*. 2013;34(3):427-435.

47. Ong P, Grosu HB, Debiane L, et al. Long-term quality-adjusted survival following therapeutic bronchoscopy for malignant central airway obstruction. *Thorax*. 2019;74(2):141-156.

48. Mahmood K, Frazer-Green L, Gonzalez AV, et al. Management of Central Airway Obstruction: An American College of Chest Physicians Clinical Practice Guideline. *Chest* 2025; 167:283.

49. Chhajed PN, Baty F, Pless M, Somandin S, Tamm M, Brutsche MH. Outcome of treated advanced non-small cell lung cancer with and without central airway obstruction. *Chest*. 2006;130(6):1803-1807.

50. Mohsenifar Z, Jasper AC, Koerner SK. Physiologic assessment of lung function in patients undergoing laser photoresection of tracheobronchial tumors. *Chest*. 1988;93(1):65-9.

51. Vergnon JM, Costes F, Bayon MC, Emonot A. Efficacy of tracheal and bronchial stent placement on respiratory functional tests. *Chest*. 1995;107(3):741-6.

52. Mahmud T, Hafeez A, Saqib M. Rapid improvement of opaque hemithorax. Endobronchial tumor debulking using electrocautery, laser and argon plasma coagulation. *Pak J Chest Med*. 2016;22(2):121-6.

53. George PJ, Clarke G, Tolfree S, et al. Changes in regional ventilation and perfusion of the lung after endoscopic laser treatment. *Thorax* 1990; 45: 248-253.

54. Vishwanath G, Madan K, Bal A, Aggarwal AN, Gupta D, Agarwal R. Rigid bronchoscopy and mechanical debulking in the management of central airway tumors: an Indian experience.

Journal of bronchology & interventional pulmonology. 2013;20(2):127-133.

55. Nair A, Godoy MC, Holden EL, Madden BP, Chua F, Ost DE et al. Multidetector CT and postprocessing in planning and assisting in minimally invasive bronchoscopic airway interventions. *Radiographics*. 2012 Sep–Oct;32(5): E201-32.
56. Du Rand IA, Barber PV, Goldring J, Lewis RA, Mandal S, Munavvar M, Rintoul RC, Shah PL, Singh S, Slade MG, Woolley A; British Thoracic Society Interventional Bronchoscopy Guideline Group. British Thoracic Society guideline for advanced diagnostic and therapeutic flexible bronchoscopy in adults. *Thorax*. 2011 Nov;66 Suppl 3:iii1-21.
57. Kahriman B, Satici C, Sokucu SN, Dalar L, Ozdemir C. Diagnostic and Therapeutic Role of Electrocautery Snare Use in Endobronchial Polypoid Lesions. *Respir Med Res*. 2024 Jun;85:101074. doi: 10.1016/j.resmer.2023.101074.
58. Van Boxem TJ, Venmans BJ, Schramel FM, et al. Radiographically occult lung cancer treated with fibreoptic bronchoscopic electrocautery: a pilot study of a simple and inexpensive technique. *Eur Respir J* 1998;11:169e72.
59. Horinouchi H, Miyazawa T, Takada K, et al. Safety study of endobronchial electrocautery for tracheobronchial lesions: multicenter prospective study. *J Bronchol* 2008;15:228e32.
60. Reichle G, Freitag L, Kullmann HJ, et al. [Argon plasma coagulation in bronchology: a new method--alternative or complementary?]. *Pneumologie* 2000; 54:508.
61. Crosta C, Spaggiari L, De Stefano A, et al. Endoscopic argon plasma coagulation for palliative treatment of malignant airway obstructions: early results in 47 cases. *Lung Cancer* 2001; 33:75.
62. Khemasuwan D, Mehta AC, Wang KP. Past, present, and future of endobronchial laser photoresection. *J Thorac Dis* 2015;7:S380-8.
63. Noppen M, Meysman M, Van Herreweghe R, et al. Bronchoscopic cryotherapy: preliminary experience. *Acta Clin Belg* 2001; 56:73.
64. Hetzel M, Hetzel J, Schumann C, et al. Cryorecanalization: a new approach for the immediate management of acute airway obstruction. *J Thorac Cardiovasc Surg* 2004;127:1427-31.
65. Moore RF, Lile DJ, Abbas AE. Current status of spray cryotherapy for airway disease. *J Thorac Dis* 2017;9:S122-9.
66. Hewlett JC, Rickman OB, Lentz RJ, Prakash UB, Maldonado F. Foreign body aspiration in adult airways: therapeutic approach. *J Thorac Dis*. 2017;9(9):3398-3409.
67. Mahmud T, Ramzan M, Saqib M, Mal G, Hafeez A. Bronchial Foreign Bodies Retrieval Using Flexible Fiberoptic Bronchoscope. *PJCM*. 2017;23(3):82-92.
68. Lund ME. Foreign body removal. In: *Principles and Practice of Interventional Pulmonology*, 2013. p.477-488.
69. Mehta AC, Khemasuwan D. A foreign body of a different kind: Pill aspiration. *Ann Thorac Med* 2014; 9:1.
70. Walls, Ron M, Murphy, F. Foreign body in the adult airway. In: *Manual of Emergency Airway Management*, Fourth Ed., Wolters kluwer/Lippicott Williams and Wilkins, Philadelphia p.419-423.
71. Mahmud T. Obstructive fibrinous tracheal pseudomembrane post-intubation; A rare yet critical complication. *JPMA*. 2026.
72. Davidson K, Shojaee S. Managing massive hemoptysis. *Chest*. 2020;157(1):77-88.
73. Sakr L, Dutau H. Massive hemoptysis: an update on the role of bronchoscopy in diagnosis

and management. *Respiration* 2010; 80:38.

74.Xing X, Liu J, Xu S, et al. Research advances in Dieulafoy's disease of the bronchus (Review). *Exp Ther Med* 2022; 23:100.

75.Mahmud T, Tahir SN. Bronchoscopic Resection of Inflammatory Myofibroblastic Tumour: A Rare Cause of Recurrent Haemoptysis and Lobar Atelectasis. *JCPSP Case Rep.* 2025;3:150-152.

76.Dweik RA, Stoller JK. Role of bronchoscopy in massive hemoptysis. *Clin Chest Med.* 1999;20(1):89-105.

77.Alraiyes AH, Machuzak MS. Rigid bronchoscopy, *Semin respire Crit Care Med.* 2014;35(6):671-680.

78.Mahmood K, Wahidi MM, Thomas S, et al. Therapeutic bronchoscopy improves spirometry, quality of life, and survival in central airway obstruction. *Respiration.* 2015;89(5):404-413.

79.Farzanegan R, Zangi M, Abbasidezfouli A, Pejhan S, Sadeghbeigee F, Daneshvarkakhi A et al. Postintubation Multisegmental Tracheal Stenosis: A 24-Year Experience. *Ann Thorac Surg.* 2021 Oct;112(4):1101-1108.

80.Dalar L, Karasulu L, Abul Y, Özdemir C, Sökücü SN, Tarhan M, Altin S. Bronchoscopic Treatment in the Management of Benign Tracheal Stenosis: Choices for Simple and Complex Tracheal Stenosis. *Ann Thorac Surg.* 2016 Apr;101(4):1310-7.

81.Kajiwara N, Kakahana M, Usuda J, Ohira T, Kawate N, Ikeda N. Interventional management for benign airway tumors in relation to location, size, character and morphology. *J Thorac Dis.* 2011;3(4):221-230.

82.Juarez MM, Albertson TE, Chan AL. Interventional bronchoscopy for obstructing benign airway tumors: which modality is ideal? *J Thorac Dis.* 2011;3(4):217-218.

83.Ayub A, Al-Ayoubi AM, Bhora FY. Stents for airway strictures: selection and results. *J Thorac Dis.* 2017 Mar;9(Suppl 2):S116-S121.

84.Han L, Peck EW, Teo E, See KC. Systematic review comparing the efficacy and safety of covered and uncovered self-expanding metal stents in benign airway stenosis. *World J Meta-Anal* 2025; 13(1): 100176.

85.Puma F, Ragusa M, Avenia N, et al. The role of silicone stents in the treatment of cicatricial tracheal stenoses. *J Thorac Cardiovasc Surg* 2000; 120:1064.

86.Cosano Povedano A, Muñoz Cabrera L, Cosano Povedano FJ, et al. [Endoscopic treatment of central airway stenosis: five years' experience]. *Arch Bronconeumol* 2005; 41:322.

87.Mongiello D, Pagliarulo V, Perri L, Pourmolkara D, Puma F, Natale G, Orlandi R, Sollitto F, Cioffi U, Guttadauro A, Raveglia F, Fiorelli A, Loizzi D. Treatment of Malignant Tracheobronchial Stenosis with Y-Shaped Stent: A Multicenter Retrospective Study. *J Clin Med.* 2026 Jan 25;15(3):966.

88.Food and Drug Administration. FDA public health notification: complications from metallic tracheal stents in patients with benign airway disorders, 2005 www.fda.gov/cdrh/safety/072905-tracheal.html (Accessed on January 15, 2007).

89.Oki M, Saka H. Double Y-stenting for tracheobronchial stenosis. *Eur Respir J* 2012; 40:1483.

90.Dooms C, De Keukeleire T, Janssens A, Carron K. Performance of fully covered self-expanding metallic stents in benign airway strictures. *Respiration* 2009; 77:420.

91.Dumon JF, Cavaliere S, Diaz-Jimenez JP, et al. Seven year experience with the Dumon

prosthesis. *J Bronchol* 1996; 3:6.

92. Madden BP, Loke TK, Sheth AC. Do expandable metallic airway stents have a role in the management of patients with benign tracheobronchial disease? *Ann Thorac Surg* 2006; 82:274.

93. Miyazawa T, Miyazu Y, Iwamoto Y, et al. Stenting at the flow-limiting segment in tracheobronchial stenosis due to lung cancer. *Am J Respir Crit Care Med* 2004; 169:1096.

94. Zakaluzny SA, Lane JD, Mair EA. Complications of tracheobronchial airway stents. *Otolaryngol Head Neck Surg* 2003; 128:478.

95. Grosu HB, Eapen GA, Morice RC, et al. Stents are associated with increased risk of respiratory infections in patients undergoing airway interventions for malignant airways disease. *Chest* 2013; 144:441.

96. Alazemi S, Lunn W, Majid A, et al. Outcomes, health-care resources use, and costs of endoscopic removal of metallic airway stents. *Chest* 2010; 138:350.

97. Ernst A, Wahidi MM, Read CA, et al. Adult bronchoscopy training: current state and suggestions for the future: CHEST Expert Panel report. *Chest*. 2015;148(2):321-332.

98. Murn M, Burbano AV, Lara JC, Swenson K, Beattie J, Parikh M, Majid A. Safety and efficacy of rigid bronchoscopy-guided percutaneous dilational tracheostomy: a single-center experience. *J Bronchology Interv Pulmonol*. 2024 Oct 30;32(1):e0990.

99. Mullon JJ, Burkart KM, Silvestri G, et al. Interventional Pulmonology Fellowship Accreditation Standards: Executive Summary of the Multisociety Interventional Pulmonology Fellowship Accreditation Committee. *Chest*. 2017;151(5):1114-1121.

100. Gafford JB, Webster S, Dillon N, et al. A concentric tube robot system for rigid bronchoscopy: a feasibility study on central airway obstruction removal. *Ann Biomed Eng* 2020; 48: 181–191.

101. Bian GB, Zhang MY, Ye Q, et al. Accurate shape and tip-contact-force estimation of multisegment continuum-robotic tubular bronchoscopes. *IEEE/ASME Trans Mechatronics* 2025; in press [<https://doi.org/10.1109/TMECH.2024.3523971>].

Appendices

Rigid Bronchoscopy: Informed Written Consent

Rigid bronchoscopy is an invasive procedure performed under general anesthesia for selected indications including but not limited to central airway obstruction, foreign body removal, tumour debulking, stent placement, and massive hemoptysis. Valid informed written consent is mandatory under the Pakistan Medical & Dental Council (PMDC) Code of Ethics (2023). Consent must be voluntary, written, and based on complete understandable information.

Table 4. Required Information for the Patient (Verbal + Written)

Disposition	Indications
Procedure	Rigid metal tube passed through mouth, past vocal cords into trachea under general anesthesia.
Indication	Specific reason (e.g., airway blockage, foreign body, bleeding, stent).
Benefits	Relief of breathlessness, bleeding control, airway opening, diagnosis.
Alternatives	Flexible bronchoscopy, surgery, radiotherapy, or medical management.

Table 5. Risks and Complications

Complication	Approximate Frequency
Dental/laryngeal injury, sore throat	Common (5–10%)
Hypoxia, minor bleeding	2–5%
Pneumothorax, pneumomediastinum	1–3%
Major hemorrhage, airway perforation	<2%
Stent migration (if stent placed)	5–15%
Cardiac arrest, death	<0.5%

Consent Form Minimum Content (see sample in English and Urdu below)

- Patient name, age, CNIC/B-form, hospital number
- Procedure name and planned interventions
- Operator name and designation
- Anaesthesia type (general)
- Acknowledgment statement: "I understand the procedure, alternatives, and risks including bleeding, airway injury, pneumothorax, infection, stent migration (if applicable), and death."
- Consent for additional emergency interventions (blood transfusion, chest tube, surgery)
- Photograph/video consent (separate if for publication)
- Refusal statement (if applicable)
- Signatures: Patient/guardian, operator, witness

Table 6. Special Situations in Pakistan

Situation	Action Required
Illiterate patient	Read consent aloud in patient's mother tongue (Urdu/Punjabi/Sindhi/Pashto) in presence of witness. Thumbprint instead of signature. Witness signs confirmation.
Emergency – unconscious, no guardian	Proceed under "doctrine of necessity" with second physician's documented independent opinion. Attempt to contact family.
Child (<18 years)	Consent from parent or legal guardian. Assent from child when appropriate.
HIV/Hepatitis positive	No denial of procedure; universal precautions apply.

Documentation Requirements

- Signed original consent must be in medical record before procedure.
- Operator must document in procedure note: consent obtained, discussion of risks/benefits/alternatives, questions answered, no coercion.
- Consent valid for single procedure only.

Legal Note

Failure to obtain valid informed consent can constitute medical negligence under Pakistan Penal Code and PM&DC Professional Misconduct Ordinance. Signed consent form must be retained for 10 years after last patient contact.

References

1. Du Rand IA, et al. Thorax. 2013;68(Suppl 1):i1-i44.
 2. Mahmud T, et al. Pak J Chest Med. 2025;31(1):22-27.
 3. PM&DC. Code of Ethics for Healthcare Professionals in Pakistan. 2023.
- Wahidi MM, et al. Chest. 2021;159(3):1178-1191.

Rigid Bronchoscopy Report Template

1. Patient & Procedure Details

Patient: MRN: [MRN] Age/Sex: [Age/Sex]

Date/Time: [DD/MM/YYYY, HH:MM] Location: [OT/Endoscopy Suite]

Bronchoscopist: Anesthetist: Assistants:

Referring Physician:

Indication: [Foreign body / Central airway stenosis / Hemoptysis / Stent placement / Other]

2. Procedure Details

Informed consent: [Taken]

Anesthesia: [General anesthesia, agent/dose] Ventilation:

Rigid Bronchoscope: Route:

Adjuncts: [Flexible bronchoscopy Y/N] [Fluoroscopy Y/N]

3. Airway Findings

Larynx/Subglottis/Trachea: [Patency, secretions, lesions, granulation, stenosis grade]

Carina: [Normal/Blunted]

Right Bronchial Tree: [RUL, RML, RLL – patency, mucosa, obstruction]

Left Bronchial Tree: [LUL, Lingula, LLL – patency, mucosa, obstruction]

Additional Findings: [Foreign body type/location, tumor, clot, stricture, size, consistency]

4. Interventions Performed

[] Foreign body removal: [Type, location, instrument used]

[] Airway dilatation: [Balloon size / Rigid barrel size]

[] Debulking: [Cryotherapy / Electrocautery / Laser]

[] Stent deployment:

[] Hemostasis: [Method used]

Technical Note: Scope and instruments withdrawn en bloc. Airway re-inspected post-procedure. [Type][size][position]

5. Specimens Obtained

[] Biopsy [] Brushing [] BAL [] TBNA [] Microbiology [] Cytology []

Histopathology

Site: [Anatomical site for each specimen]

6. Complications

[] None [] Bleeding [] Hypoxemia [] Airway trauma [] Loss of foreign body []

Pneumothorax

Management: [Details if any]

7. Impression/conclusion

[Brief interpretation of findings and procedure outcome]

8. Plan & Recommendations

[] Await pathology/microbiology

[] Follow-up bronchoscopy on

[] Further imaging/intervention:

[] Post-procedure care: [Date][Details][Instructions]

9. Documentation

Images/Video: [Attached Y/N, file names/IDs]

Bronchoscopist Signature: _*_*_ Date: _*_*_

**Youtube: <https://www.youtube.com/watch?v=0vUobn62jeo>
2 Fundamentals Bronchoscopy Reports
(Prof Henri Colt, Bronchoscopy International)-2026**



Further Reading:

- WABIP textbook of Interventional Pulmonology. Ali Musani, Levent Dalar. 2025
https://www.wabip.com/wp-content/uploads/institute/ipi_textbook.pdf
- The utility of a rigid bronchoscope. Athanassiadi K, Na KJ, Zanoska K, et al. *Breathe* 2025; 21: 240252. doi: 10.1183/20734735.0252-2024.
- Management of Central Airway Obstruction: An American College of Chest Physicians Clinical Practice Guideline. Mahmood K, Frazer-Green L, Gonzalez AV et al. *Chest*. 2025 Jan;167(1):283-295. doi: 10.1016/j.chest.2024.06.3804.
- BTS Interventional Bronchoscopy Guideline Group. Summary of the British Thoracic Society guidelines for advanced diagnostic and therapeutic flexible bronchoscopy in adults. Du Rand IA, Barber PV, Goldring J et al. *Thorax*. 2011 Nov;66(11):1014-5. doi: 10.1136/thoraxjnl-2011-201052.
- Bronchoscopy Academy. Learn bronchoscopy from Dr. Henri Colt and the experts at Bronchoscopy International youtube.com.
<https://youtube.com/@bronchoscopy?si=VtUkdg1NNv3m0AQs>
- Prof Dr Talha Mahmud's Interventional Pulmonology:
<https://www.youtube.com/shorts/U543MFC7nY0:UCPSaTFeNF8UXyoYNMDYII9g>

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