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# REVIEW ARTICLE

# PRINCIPLES OF INTERVENTIONAL THERAPEUTIC BRONCHOSCOPY

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## INTRODUCTION

Interventional therapeutic bronchoscopy (ITB) is an evolving field within pulmonary medicine that focuses on application of advanced bronchoscopic techniques for the treatment of various malignant and nonmalignant airway disorders. Therapeutic procedures pertaining to these disorders include, but are not limited to, rigid bronchoscopy (RB), laser bronchoscopy, endobronchial electrosurgery, argon-plasma coagulation, cryotherapy, airway stent insertion, balloon bronchoplasty and dilatation techniques, endobronchial radiation (brachytherapy) and photodynamic therapy. In order to perform an interventional procedure, a well-equipped facility, competent personnel, preprocedure evaluation and monitoring are mandatory.[1,2] In this article; we present an overview of principles of ITB.

***Indications for ITB:***

- Life-threatening obstruction of the central airways (i.e. trachea, mainstem bronchi and bronchus intermedius).[1-3]
- Central airway obstruction (CAO) causing symptoms (dyspnea, atelectasis, post-obstructive pneumonia, hemoptysis or reducing the airway lumen >50%).[1-3]
- Inoperable early lung cancer amenable to bronchoscopic treatment.[3] (Details of this indication is beyond the scope of this article).

The etiologies of CAO include malignant airway disorders (e.g., primary bronchogenic carcinoma and metastatic malignancy to the bronchi) and nonmalignant airway disorders (e.g., sarcoidosis, amyloidosis, relapsing polychondritis, infectious complications of tuberculosis, histoplasmosis or coccidioidomycosis, complications of lung transplantation, foreign body inhalation and sequelae from the introduction of artificial airways).[2]

***Fundamentals needed to start ITB practice***

***Bronchoscopy unit:*** Comprehensive practice of ITB requires a dedicated unit where a large number of specialized bronchoscopy procedures to be performed on regular basis. The major advantage of a dedicated bronchoscopy unit is the availability of any type of instrument and the facility to perform all types of bronchoscopy-related procedures and to handle any complication encountered. The need for dedicated bronchoscopy unit should determine by the number of procedures performed in a given time period at any medical center as well as the expertise of physician who practice bronchoscopy and related procedures. A dedicated bronchoscopy unit consists of a predefined physical location where the procedures are performed, all equipment necessary to provide bronchoscopy and related procedures, facilities to administer general anesthesia and a bronchoscopy team.[4]

The unit should be accessible for a stretcher or bed, and the examination table should be accessible from all sides. Dimming of daylight is essential. The size of the suite and placement of the equipment should allow for minimum interference between the bronchoscopist, anesthesiologist, and nursing personnel. To enhance cooperation, it is recommended that procedures be performed under video observation. Patients should undergo preparation and recovery in a separate room that is equipped with an oxygen supply, vacuum suction, and adequate monitoring.[1]

### *Equipments*

The types of equipments required depend on the needs and the type of bronchoscopy practice. The required equipments to perform ITB include flexible and rigid bronchoscopy of variable sizes to accommodate adults as well as pediatric patients, light source, video equipment, anesthesia machine, cardiorespiratory monitoring and resuscitation equipment, several biopsy forceps, suction apparatus and supplemental oxygen. Selection of one or more of other interventional equipments as laser bronchoscopy, electrocautery, argon-plasma coagulation, cryotherapy, airway stent insertion, brachytherapy and phototherapy depends on needs and the expertise of ITB team.[4]

### *Trained Personnel*

The bronchoscopist, anesthesiologist, and nursing staff should have appropriate training for the procedure to be performed. The anesthesiologist should be proficient with conventional, jet, and single-lung ventilation. For ITB at least one to two nursing assistants are needed.[1] Bronchoscopy should be performed by physicians who are skilled and appropriately trained in the procedure.[4] Current venues for training consist of dedicated 1-year interventional pulmonology (IP) fellowships, extended sabbaticals in IP centers, and 1- to 3-day condensed courses in selected procedures that are offered throughout the world.[2] The decision whether someone is competent to perform ITB should not be based on numbers of bronchoscopies performed only, but the director of bronchoscopy at the training institution should judge and certify the competence of each candidate and recommend and provide remedial training if necessary.[2,4] Training in rigid bronchoscopy should be reserved for physicians who have had extensive experience with flexible bronchoscopy and endotracheal intubation. Trainees should first practice on mannequins or animal models and should perform at least 20 supervised rigid bronchoscopy procedures before attempting this procedure alone. To maintain competency, the procedure should be performed at least 10–15 times·yr-1. Training in laser bronchoscopy, electrocautery, cryotherapy, airway stent insertion, brachytherapy and phototherapy should be reserved for a trainee who has had ample experience with rigid/flexible bronchoscopy and endotracheal intubation. Trainees should first practice on inanimate or animal models. They should perform ≥10 supervised procedures before attempting this procedure alone. In order to maintain competence, 5–10 procedures·yr-1 should be performed. Laser bronchoscopy requires double the previous numbers.[1]

### *Preprocedure evaluation and Monitoring*

Before any procedure, the patient's history must be taken and a thorough physical examination must be given. For appropriate patient selection, the physician must obtain information on previous therapies, comorbidities and current performance status. Laboratory tests (e.g. complete blood count, electrolytes, coagulation profile, electrocardiogram, chest radiograph) are recommended. Additional studies such as computed tomography (CT), pulmonary function tests, and assessment of arterial blood gases may be required depending on the nature of the procedure. The preoperative evaluation should ideally establish that the lung beyond the obstruction is viable and that dyspnea is effectively related to the obstruction.[1] (Fig. 1) schematically illustrates the three main types of malignant airway obstruction.

The majority of ITB are practiced using the RB under general anesthesia. Some ITB procedures can be performed by flexible bronchoscopy either under general or local anesthesia with conscious sedation. Monitoring during ITB include continuous pulse oxymetry, electrocardiogram, intermittent noninvasive measurement of blood pressure. In addition capnography and monitoring of neuromuscular relaxation is required if general anesthesia and neuromuscular relaxation are performed.[7]

***Principles of therapeutic bronchoscopic treatment***

***The principles of therapeutic bronchoscopic treatment are:***[3]

- To reopen obstructed airways (and, hence, relieve dyspnea, post-obstructive infection and atelectasis);
- To maintain established airway patency (and, hence, prevent recurrence of obstructive symptoms, and to allow for concomitant non-endoscopic therapy such as chemo/radiotherapy which often are contraindicated in cases of postobstructive complications) and
- To treat specific symptoms (e.g. hemoptysis, cough, stridor...).

***Different bronchoscopic techniques can hence be classified relative to the above mentioned treatment principles and indications:***[3]

- Techniques enabling rapid removal of obstruction (e.g. mechanical debulking/resection: laser resection, electrocautery) in case of life-threatening obstruction.
- Techniques enabling delayed removal of obstruction (e.g. cryotherapy, endobronchial irradiation, photodynamic therapy) in cases of non-critical stenosis.
- Techniques enabling maintenance of airway patency (e.g. stenting).
- Techniques enabling symptom control such as hemoptysis (e.g. argon plasma coagulation, electrocautery, laser therapy, ...).

***The choice of the initial bronchoscopic treatment technique depends on various factors:***[3]

- The urgency of the intervention (e.g. imminent suffocation);
- The nature and extent of the obstruction (e.g. intraluminal versus extraluminal disease);
- The available equipment, expertise and logistics.

***Spectrum of ITB***

Advances in bronchoscopic tools and techniques have provided interventional pulmonologists with a wide array of therapeutic options that can be used individually or in combination to match the needs of all patients. RB has seen resurgence in the last 2 decades. The renewed interest stemmed from the recognition of the advantages of RB, such as the ability to ventilate the patient while intervening in the airways, the capability of using large-suction catheters to aspirate blood or debris, and the utility of the barrel of the rigid bronchoscope in "coring out" tumor tissue and dilating stenosis.[2]

There are many indications for therapeutic RB including bleeding or hemorrhage, foreign body extraction, dilation of tracheal or bronchial strictures, relief of airway obstruction and insertion of stents.[1] Flexible bronchoscopy in these instances is not optimal due to the small size of its lens and working channel, and the possibility of converting stable airways in marginal patients into a life-threatening respiratory emergency. During RB, a variety of flexible bronchoscopes are routinely used to access angulated or distal airways and to facilitate the debridement process in these locations.[2]

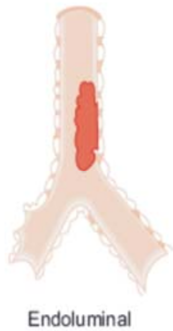
Mechanical debridement of large airway tumors is accomplished through coring by the beveled tip of the RB or by grasping large pieces with rigid forceps.[5,7] This approach is often combined with different endobronchial tumor ablation tools.

Tumor destruction can also be accomplished with variety of endobronchial tools including heat therapy a (e.g., laser therapy, electrocautery, argon plasma coagulation), photodynamic therapy, cryotherapy, or brachytherapy[2] Table 1. Although some forms of heat therapy (i.e., laser therapy and electrocautery) can be used to directly vaporize tumor tissue, they are often used to coagulate tissue prior to mechanical debridement, in a fashion known as heat-assisted mechanical debulking (Fig. 2). Increasingly, electrocautery and argon plasma coagulation are replacing laser therapy as the method of choice for coagulation and vaporization in the airways due to their lower cost, less cumbersome setup, easier use, and more favorable safety profile.[2]

**Table 1-Comparison of Currently Available Bronchoscopic Ablative Therapies**

| Modality | Mechanism | Effect | Advantages | Disadvantages |
|---|---|---|---|---|
| Nd:YAG laser | Thermal energy produced by laser light | Coagulation and vaporization of tissue | Excellent debulking | Expensive; cumbersome setup |
| Electrocautery | Thermal energy produced by an electrical current | Coagulation of tissue but more superficial effect than laser | Excellent safety profile; multiple instrument designs; inexpensive | Contact mode requiring frequent cleaning of probe |
| Argon plasma coagulation | Thermal energy produced by the interaction between argon gas and an electrical current | Superficial coagulation of tissue | No undesired deep tissue effects | Ineffective for in-depth tissue coagulation or debulking |
| Photodynamic therapy | Injection of a photosensitizer followed by the destruction of presensitized tumor cells through illumination with nonthermal laser | Delayed destruction of tissue (24–48 h) | Relatively long-lasting effects | Expensive; need for multiple bronchoscopies; skin photosensitivity lasting up to 6 wk |
| Brachytherapy | Direct delivery of radiation therapy into the airway | Delayed and in-depth destruction of tissue | Long-lasting effect; synergistic with external beam radiation | Higher incidence of complications, particularly hemorrhage |
| Cryotherapy | Destruction of tissue by alternating cycles of freezing to extreme cold temperatures and thawing | Delayed destruction of tissue (1–2 wk) | Good tool for retrieval of foreign objects and removal of large mucus plugs or clots | Not suitable for debulking in acute airway obstruction; need for multiple bronchoscopies |

Reproduced from [2].



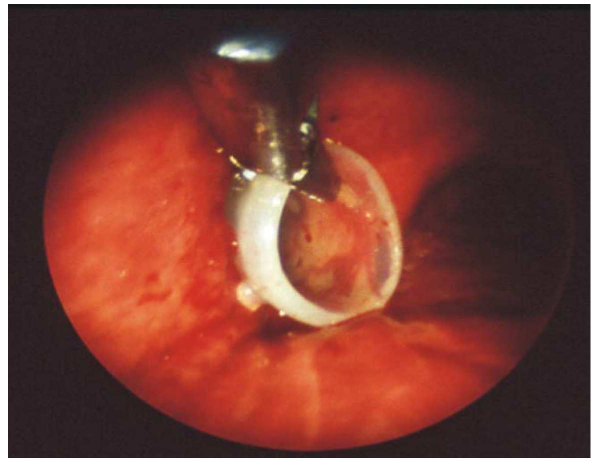
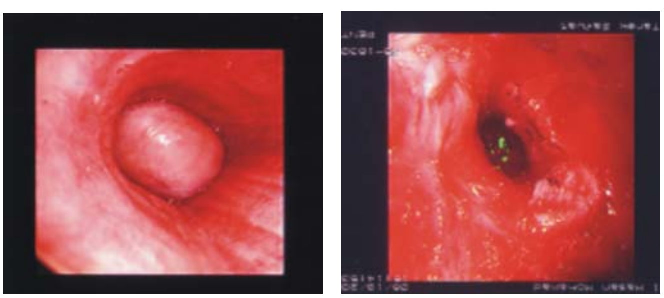



*Fig 1. Schematic illustration of the three basic types of central airway stenosis; a 50% obstruction at the level of the distal trachea is chosen for each type. Reproduced from (1,5).*

*Fig 3. Bronchoscopic picture showing Dumon silicone stent insertion in left main bronchus.*



**A** **B**

*Fig 2. Bronchoscopic picture showing carcinoid tumor mass (a) obstructing left main bronchus. After laser therapy, the left main bronchus (b) is patent endoscopically.*

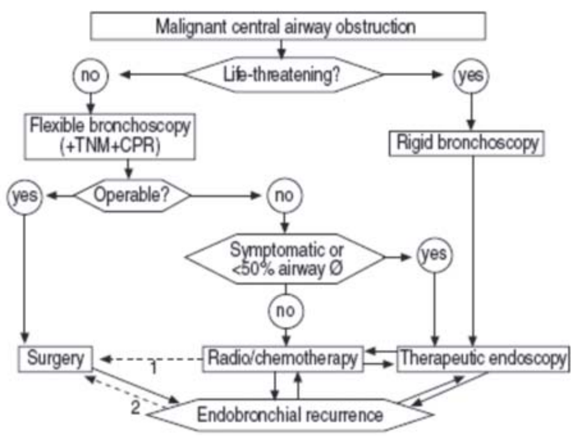



*Fig 4. Algorithm for the management of malignant central airway obstructions. Terms in hexagonal boxes are conditions; terms in rectangular boxes are procedures. Two-way arrows indicate the tendency of endobronchial tumours to recur and the repetitive need of multimodality treatment. Interrupted arrows: 1: rare cases of primarily inoperable lung cancers which become secondarily operable after initial therapeutic bronchoscopy usually followed by neo-adjuvant treatment; 2: rare cases of operated lung cancers initially presenting with central airway obstruction and still being operable after careful restaging of an endobronchial recurrence. TNM: tumour staging, including histology; CPR: cardiopulmonary reserves of the patient. Reproduced from.(1)*

Airway stents are hollow prosthetic devices used to re-establish airway patency, either to support the tracheobronchial wall in stenosis or malacia or to seal off airway fistulas. Indications for airway stenting are: 1) extrinsic stenosis of central airways with or without intraluminal components due to malignant or benign disorders; 2) complex, inoperable tracheobronchial strictures; 3) tracheobronchial malacia; 4) palliation of recurrent intraluminal tumor growth; and 5) central airway fistulae (esophagus, mediastinum, pleura).(1) Airway stents come in the following two varieties: metallic and silicone. Metallic stents with partial silicone covers are also available.(2)

Dumon stent is inserted using the rigid bronchoscope and has probably been the most common silicone stent used in the last decade (Fig. 3). The advantages include that it can be easily repositioned or removed; it provides a solid barrier to prevent encroachment of tumor and is relatively cheaper than the metallic stents. The disadvantages of this stent type include its tendency to migration, relatively unfavorable wall to-lumen ratio, mucous retention, lack of flexibility in conforming to tortuous airways and the possibility to stimulate formation of granulation tissue.(7) Metallic stents can be placed via flexible bronchoscopy or RB, with or without fluoroscopy. Growth of the bronchial mucosa over the metallic wires leads to endothelialization of the stent, and is the likely explanation for the lower migration rate and the decreased interference with the mucociliary clearance of secretions. While metallic stents function exceedingly well in airways afflicted by invasive cancer, they have not faired as well in airways afflicted by benign diseases because of their long-term complications, including obstructive granulation tissue, stent fracture, and difficult and perilous removal.(2)

With the availability of effective local therapy for the airway, the paradigm of primary treatment in patients with malignant airway obstruction is shifting from external beam radiation with its delayed effect to ITB.(2) Now the treatment of choice for patients with malignant CAO is multimodality treatment which is combination of various endoscopic therapeutic techniques with nonendoscopic modalities (e.g. external beam radiation or chemotherapy) to treat malignant tracheobronchial lesions (Fig. 4).(1) If ITB capabilities are available, first-line endoscopic interventions should now be strongly considered due to more immediate results and a favorable safety profile. Radiation therapy can then often be performed in a stable patient with an improved performance status to consolidate the effect of endoscopic therapy.(2)

Finally, ITB has quickly gained recognition and drawn interest with allure in "instant gratification" associated with immediate procedural success, the introduction and use of new technologies and treatments, and the sense of empowerment felt with the ability to perform a series of therapeutic interventions by a single physician to the benefit of the patient.

However, the reality does not mirror the perceived image, and there are numerous problems facing IB. The territorial battles with other disciplines, financial concerns, training, verification of competency and lack of rigorous scientific research in this field are the main challenges and future directions facing ITB.(2)

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