Rigid Bronchoscopy

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KEYWORDS
- Interventional pulmonology • Interventional bronchoscopy • Rigid bronchoscopy
- Flexible bronchoscopy • Airway stenting • Airway obstruction • Airway stenosis

KEY POINTS
- The rigid bronchoscope is the instrument of choice in most bronchoscopic therapeutic procedures.
- The rigid bronchoscope is not only a tool to visualize the airway but also a therapeutic instrument in itself or in association with other endoscopic techniques.
- Most of the scientific associations agree on this point.
- Rigid bronchoscopy requires training and a dedicated facility or easy access to an operating room with anesthetic support.
- Rigid bronchoscopy is mandatory in airway stenting when using silicone stents, which still represent the gold standard. Interventional bronchoscopy is a minimally invasive option in a variety of cases, and can occasionally represent a bridge to definitive surgical management.
- If there are surgical contraindications, endoscopic techniques are acceptable definitive palliation interventions.

HISTORICAL BACKGROUND

Gustav Killian first described rigid bronchoscopy for therapeutic airway indications in Freiburg (Germany) in 1895. The first reported procedure involved the removal of a pork bone from the bronchus of a farmer using a rigid esophagoscope. Killian continued to experiment with rigid tubes in both cadavers and patients and, in 1898, described the successful removal of foreign bodies (FBs) in 3 more cases. The technique was further advanced by the discovery of the anesthetizing effect of locally applied cocaine. At the same time, on the other side of the Atlantic Ocean, Chevalier Jackson was instrumental in developing the modern rigid bronchoscope. In 1904, he developed an endoscope with a small light at the distal end. He pioneered endobronchial treatment of the complications of tuberculosis, which was the leading cause of airway disease during the first half of the twentieth century. He is also credited with the first reported endoluminal mechanical resections of endobronchial tumors. Other significant historical advances included the optical telescope by Broyles and the solid rod lens optical system by Hopkins.1 Modern bronchoscopy benefited from the vision of Shigeto Ikeda, a Japanese pulmonologist, who developed the flexible bronchoscope using optic fibers,1 which transformed the diagnostic work-up for lung cancer and visualization of the bronchial tree. It is less invasive, does not require, general anesthesia, and provides superior visualization of small peripheral airways. The rigid bronchoscope was regarded as obsolete and unnecessary.
was virtually abandoned in favor of the flexible bronchoscope. Few endoscopists were exposed to the technique and adequate training became a rarity.

However, some European physicians continued to use the rigid system for the treatment of airway diseases, including Jean-François Dumon, who is regarded as a pioneer in interventional pulmonary medicine. He was one of the first bronchoscopists to use laser therapy in the airway and standardized its use. Another major advance was the invention of a dedicated silicone stent for the trachea and bronchi. Before the era of the Dumon stents, the only available option for reestablishing patency of the trachea after surgery was the Montgomery T tube, which required a tracheotomy for placement. The combination of laser debulking of the endoluminal component and postresection endotracheal stent placement when there is concurrent extrinsic compression allowed immediate and lasting palliation of malignant central airway obstruction, which allowed pulmonologists to treat central airway diseases that had formerly been considered either untreatable or treatable only via extensive, and often prohibitively dangerous, surgical procedures.

RIGID BRONCHOSCOPY EQUIPMENT

The modern rigid bronchoscope is a straight, hollow stainless steel tube that has not significantly changed from the equipment developed by Chevalier Jackson. It is available in various lengths and diameters ranging from 5 mm to 13.5 mm. The barrel wall is 2 to 3 mm thick and the internal diameter is uniform throughout. The distal end of most bronchosopes is beveled, allowing atraumatic passage through the vocal cords. The bevel can also be used to core out an endobronchial tumor and to corkscrew the bronchoscope through tight stenoses. Slits in the distal wall of the bronchoscope allow contralateral ventilation during intubation of a main bronchus. The tracheoscope is shorter in length than the bronchoscope and has no ventilation slits. The proximal end of the bronchoscope consists of a central opening and various side ports for connection of jet ventilation or conventional ventilation devices as well as a source of illumination. The EFER-Dumon rigid bronchoscope, as manufactured by EFER Endoscopy (La Ciotat, France) has a universal proximal head that can be connected to all the bronchoscope barrels. In addition, the various barrel sizes are color coded. Other manufacturers of rigid bronchoscopy equipment include the Texas rigid integrated bronchoscope (Fig. 2) from Richard Wolf (Knittlingen, Germany), the Karl Storz Rigid Bronchoscope (Tuttlingen, Germany) (Fig. 3), and, soon, the Dutau-Novatech rigid bronchoscope (La Ciotat, France) (Fig. 4). Illumination in modern rigid bronchoscopes is provided by a xenon light source with a prismatic light deflector that is attached proximally to allow full use of the bronchoscope lumen. A Hopkins rod rigid telescope is passed through the central opening of the bronchoscope barrel. The bronchoscopist can either look down the eyepiece of the telescope, or a charge-coupled chip video camera can be connected to the eyepiece for visualization on a monitor, which also allows the physician to record procedures. Before the development of the flexible bronchoscope, angled telescopes were needed to view all bronchial subdivisions, but currently most endoscopists prefer to pass a flexible bronchoscope via the barrel of the rigid bronchoscope for this purpose. The Texas rigid bronchoscope is the first fully integrated rigid bronchoscope with a semiflexible endoscope inside. The theoretic benefit of the Texas system is the full inner lumen of the rigid bronchoscope. The semiflexible endoscope is attachable to a separate channel inside the tube. Various accessory instruments, including forceps, suction catheters, laser fibers, and stent delivery systems, are used during rigid bronchoscopy by passage via the proximal opening.

RIGID BRONCHOSCOPY TECHNIQUE

After induction of anesthesia, the patient’s head is partially extended and the bronchoscope is...
introduced in the midline with the bevel anteriorly (see Fig. 4). Care should be taken to avoid trauma to the patient’s upper teeth during intubation by protection with the bronchoscopist’s finger or the use of a protective guard. The bronchoscope is advanced under the epiglottis and rotated 90° to allow atraumatic passage through the vocal cords. Once the trachea is entered, the bronchoscope is rotated back 90° and advanced to the lower trachea. To enter one side of the bronchial tree, the patient’s head is rotated toward the contralateral shoulder. When using the tracheoscope, thinner diameter bronchoscope barrels can be inserted through the lumen of the tracheoscope. There is therefore no need to remove the tracheoscope or to reintubate the patient. A flexible bronchoscope can also be passed through the lumen of the rigid bronchoscope to allow inspection of distal airways. In addition, the flexible scope is essential for airway toileting and specimen collection. Both bronchoscopes are often used by interventional pulmonologists during therapeutic bronchoscopy. An alternative technique of intubation involves the use of a laryngoscope to lift the epiglottis anteriorly and guide the passage of the bronchoscope to the level of the vocal cords.

**Rigid Bronchoscopy Indications**

The rigid bronchoscope is an invaluable tool in interventional bronchoscopy. With maximal safety and under general anesthesia, it allows adequate ventilation of the patient through a side port; efficient suctioning of blood, secretions, pus, and smoke via large suction catheters; and the use of accessory instruments (laser probes, cryoprobes, rigid forceps, and so forth). It also allows therapeutic interventions such as dilation of stenoses or extrinsic compression, and mechanical coring and debulking of endoluminal tumors using the distal sharp bevel to rapidly recanalize the airway. In addition, an FB can safely be removed using the rigid forceps. The rigid bronchoscope is the instrument of choice in cases of acute respiratory failure secondary to endoluminal obstruction, because it allows a rapid procedure while maintaining airway patency and adequate ventilation. Because of the obvious anatomic limitations, its use is not suitable for upper lobe disease. A rigid bronchoscope is required for silicone stent placement using a dedicated rigid loading system.

Treatment of central airway obstruction with a flexible bronchoscope alone is not generally recommended, particularly in the case of tracheal lesions. Its small working channel may not be sufficient to prevent airway flooding in cases of massive bleeding. Biopsy forceps have a small diameter and can only sample small tumoral fragments, leading to long and fastidious procedures. In an attempt to overcome this, metallic snares or baskets have been developed to remove large pieces of tumors or FBs. Rigid and flexible bronchoscopy remain complementary techniques, and most pulmonologists use both instruments concurrently during interventions. Flexible bronchoscopy is an important tool with easy maneuverability that allows exploration and clearing of the peripheral airways. In addition, flexible bronchoscopy is the only tool available for the treatment of upper lobe obstruction. A variety of tools (laser, thermo-coagulation, argon plasma coagulation, and cryoprobes) can be introduced in its working channel.

**FBs**

The use of rigid bronchoscopy versus flexible bronchoscopy has been widely debated in the literature. The rigid bronchoscope provides excellent access to the subglottic airways and passage of the rigid grasping forceps. Optical forceps allow direct visualization of the FB and optically guided grasping. As an alternative, a rigid telescope and a forceps can be used coaxially through the bronchoscope (Fig. 5). During the

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Fig. 3. The Storz rigid bronchoscope.

Fig. 4. The Dutau-Novatech rigid bronchoscope.
extraction procedure, it is crucial not to push the FB distally with the bronchoscope, the forceps, or the suction catheter. If blood and secretions are present proximally to the FB, these should be cleared by careful suctioning. The optical forceps is then advanced in the bronchial axis, a few millimeters proximal to the FB. For smooth and rounded FBs, the key is to grip the largest volume of the FB. In this setting, the smooth forceps (FB forceps) are preferred to the sharp alligator forceps. The forceps’ cups are opened maximally and the forceps is advanced under visual control taking care not to push the FB downwards. The FB is then gently but securely gripped. Both forceps and FB are pulled up, a few millimeters distal to the tip of the bronchoscope, and then the instruments and FB are withdrawn en bloc from the trachea. Alligator forceps are used for grasping sharp or irregular FBs. In case of large, hard FBs, such as pistachio shells, breaking the FB into 2 or 3 fragments may help extraction. In contrast, vigorous grasping of friable FBs, such as peanuts, should be avoided, because it may result in maceration and distal wedging of small fragments. Heavy FBs, such as metallic FBs, tend to move distally because of gravity; in this setting, it may be helpful to place the patient in the Trendelenburg position. During the last step of extraction, the FB can be lost accidentally, either because it is blocked in the narrow glottic area or because there was some inappropriate coaxial movement between the bronchoscope and the forceps, causing the tip of the bronchoscope to push the FB out of the forceps’ cups or jaws. If this occurs, the operator should first carefully inspect the oral cavity and the larynx with the laryngoscope and grasp the FB with a Magill forceps, if possible, before reintubating the trachea with the bronchoscope. Once the FB is removed, the trachea is reintubated with the rigid bronchoscope and the airways are carefully reexamined, ideally with a fiberoptic bronchoscope passed through the rigid tube, to rule out another FB or residual fragments.19

Silicone Stent Placement

The main purpose of stents designed for use in the central airways (trachea, mainstem bronchi, and, in select cases, lobar bronchi) is to restore patency of the airway to as close a normal caliber as possible. Any endoluminal disorder responsible for debilitating symptoms such as dyspnea and associated with a significant reduction in airway luminal diameter (greater than 50%) may be an indication for a silicone airway stent.20,21

Five major indications have been established20:

1. Extrinsic compression from tumors or lymph nodes
2. Stabilization of airway patency after endoscopic removal of intraluminally growing cancer
3. Treatment of benign strictures
4. Stabilization of collapsing airways (malacia and polychondritis)
5. Treatment of fistulas (eg, stump dehiscences or tracheoesophageal fistulas)

Endoluminally growing tumors should be treated initially by laser resection, for example, and then a stent should be placed if it is still necessary. Treating benign lesions requires particular caution,
because stents may cause harm in the long run, even if early benefit is noted.\textsuperscript{21} In general, only removable stents should be used for these indications until a multidisciplinary team has determined inoperability.\textsuperscript{21}

Airway stents are generally divided into 2 types: the silicone stents and the metallic stents.\textsuperscript{21} The Dumon stent (Tracheobronxane, Novatech, La Ciotat, France) remains the reference standard because it is the most commonly placed stent worldwide. This airway stent has a simple design consisting of a silicone tube with small studs on the external surface to reduce the risk of migration.\textsuperscript{8} They have become, de facto, the gold standard for the treatment of benign and malignant stenoses over the past 10 years.\textsuperscript{21} There are 2 specific designs: straight and \(\text{Y}\) shaped (for disease involving the carina).\textsuperscript{22} Stents are available in various lengths and diameters to accommodate both pediatric\textsuperscript{23} and adult anatomy. For irregularly shaped stenoses (ie, those with marked reduced central airway caliber compared with the extremities), specialized hourglass-shaped stents are available.\textsuperscript{24} These hourglass-shaped stents are particularly useful in cases of short benign tracheal disease. Dumon stents are ideally inserted through a dedicated rigid bronchoscope (\textbf{Fig. 6}). The commercialized introducer set includes a loading tool and a pusher. A Dumon stent can be repositioned, removed, and replaced at any time with ease using standard grasping rigid forceps.

**Malignant Airway Stenosis**

Bronchial obstruction is frequently encountered during the course of bronchial carcinoma: more than 30\% of bronchial carcinomas present with central airway obstruction.\textsuperscript{25} Such obstructions may lead to specific complications, including reduced survival and decreased quality of life.\textsuperscript{26} However, most patients die from general complications caused by their primary intrathoracic disease or extrathoracic extension, and only about 35\% from local complications (severe hemoptysis, lung infections, or asphyxia).\textsuperscript{26} Given that oncologic treatments do not generally result in prompt improvement in patients’ symptoms,\textsuperscript{27,28} endoscopic treatments are necessary adjuncts to the tailored management of patients at all stages of the disease (neoadjuvant, adjuvant, and palliative). In addition, bronchial obstruction-related complications (atelectasis, respiratory insufficiency or distress, repeated infections) are likely to interfere with optimal oncologic treatments, such as chemotherapy or radiotherapy. Malignant airway obstruction is often classified based on the type of airway involvement.\textsuperscript{29} Airway involvement can be intrinsic, limited to endoluminal involvement, an extrinsic compression, or a mixed condition with both tumor within the airway (ie, intrinsic), and external compression of the airway (ie, extrinsic).\textsuperscript{14,29} In summary,\textsuperscript{14,29} purely intrinsic involvement can often be managed with debulking techniques to remove the endoluminal tumor. The rigid bronchoscope is then the instrument of choice. Three steps can be described. The first is coagulation and devascularization of the tumor, the second is mechanical coring, and the third is coagulation of the tumoral base (\textbf{Fig. 7}). This technique is called laser (or electrocautery, or argon plasma)-assisted mechanical debulking (\textbf{Fig. 8}). On occasions, a stent may be placed as a bridge to chemoradiotherapy or alternatively may be considered as a permanent solution when the risk of local recurrence is high. Extrinsic compression without intraluminal disease is readily treated with dilation followed by stenting. Mixed (intrinsic and extrinsic) obstruction is usually managed with both debulking and stent insertion. Benefits noted after successful bronchoscopic treatment of obstruction usually last for 2 to 3 months.\textsuperscript{30} Benefit duration after stent placement is generally reported to be around 4 months before tumoral stent overgrowth,\textsuperscript{31} but this duration can be increased with the use of effective oncologic treatments (ie, chemotherapy and/or radiotherapy).\textsuperscript{32}

Other indications for endobronchial treatment include endobronchial metastases (eg, esophageal, thyroid, renal cell carcinoma, colon, and melanoma) or alternatively low-grade primary tumors (eg, adenoid cystic carcinomas, typical or atypical carcinoids).

\textbf{Fig. 6.} FB removal using the rigid bronchoscope.
Benign Airway Stenosis

Postintubation or posttracheostomy tracheal stenosis

Despite the decreasing incidence of postintubation or posttracheostomy tracheal stenosis (PITTS), management of such conditions remains challenging. Even if surgical repair (sleeve resection) is the best definitive solution, approximately 50% of patients present with acute respiratory distress prompting emergent less invasive endoscopic treatments as a bridge to surgery or as definitive treatment in cases with contraindications to surgery. Moreover, tracheal stenosis can recur after tracheal sleeve resection.

PITTS can be divided into 2 different types: the weblike PITTS (disease of the tracheal mucosa sparing the cartilaginous rings) and the complex PITTS (involving deterioration of the cartilaginous support). The weblike PITTS is generally successfully treated by radial mucosal incisions followed by mechanical dilation. The success rate is close to 90% after 1 to 3 sessions.

Fig. 7. Silicone stent placement with the rigid bronchoscope. The arrow explain the necessary rotation of the rigid bronchoscope during the dilation of a tracheal benign stenosis.

Fig. 8. The various stages of laser-assisted mechanical debulking. (A) A tumor obstructing the trachea, (B) coagulation of the lesion with laser, (C) mechanical resection using the bevel of the rigid bronchoscope, (D, E) removal of a large piece of tumor with a rigid forceps, (F) carbonization of the tumor base with laser.
complex PITTS, mechanical dilation alone is usually not sufficient. In cases of surgical contraindication, the next step is the placement of a stent to maintain the long-term patency of the tracheal lumen and prevent recurrence. The choice of stent is important. Self-expandable metallic stents (SEMS) have been shown to make potentially operable PITTS inoperable because of the severe complications associated with the technique. These prompted the US Food and Drug Administration to publish recommendations to limit the use of SEMS in benign tracheal stenosis. Silicone stents are more suitable because of their easy removal, and are not likely to jeopardize a future surgery. Long-term results (no recurrence after stent removal at 1 year) vary from 40% when the stent is placed for 6 months, up to 70% when the stent remains in place for 18 months. In addition, silicone stents require surveillance and may present complications like migrations, granulations, and/or mucus obstructions that can affect the quality of life of the patient. Migration is probably the most challenging complication in this indication, with an incidence ranging from 11% to 17.5%, especially when the stenosis is close to the vocal cords. This complication can be reduced by the use of a dedicated hourglass silicone stent or by external fixation. Endoscopic techniques represent, in about 50% of cases, an efficient treatment of PITTS, but many questions remain regarding its long-term efficacy and its impact on quality of life compared with surgery.

**Bronchial stenosis following lung transplantation**

Improvement in surgical techniques, immunosuppressive regimen, and postoperative care have resulted in improved clinical outcomes, because airway complication rates have decreased, presently ranging from 5% to 30% with an associated mortality of 2% to 3%. Several endoscopic interventions may allow effective management of lung transplantation (LT)-related airway complications. Such procedures include cryotherapy, laser photoresection, balloon bronchoplasty, electrocautery, brachytherapy, airway dilation using rigid bronchoscope, and stent placement. Stent placement is usually considered for bronchomalacia, bronchial stenosis, combined stenosis and malacia, or bronchial dehiscence when these conditions are responsible for respiratory symptoms, persistent decline in lung function, or postobstructive complications such as mucus retention and/or infection. Although many studies have previously described management of LT-related airway complications with SEMS, few data are available with regard to the use of silicone stents for this indication. Stent placement can result in mucosal ischemia, and restenosis is a common finding. Although the overall results (survival and clinical outcome) favor stent placement, a high rate of stent-related problems such as scarring, mucus plugging, bacterial colonization, and migration have to be accepted with currently available stents. It is advisable to select a stent that can be removed if necessary without causing further tissue damage. Our group recently published a retrospective study on Duman stent placement in anastomotic stenosis after LT. These stents could be removed definitively in 70% of the patients without further recurrence.

**ANESTHESIA**

Rigid bronchoscopy brings together a unique set of conditions that result in a significant challenge for the anesthetist and endoscopist alike. This includes the necessity of both specialties to share the same airway during the procedure. In addition, the underlying disease often significantly compromises the airway. Also, most patients are of advanced age and have multiple pulmonary and nonpulmonary comorbidities that complicate the management of the case.

All cases should be assessed preoperatively to address any reversible conditions that may adversely affect the outcome of the procedure. This assessment should address the cardiovascular and pulmonary systems. All imaging should be reviewed to document the location of the obstruction and assess how this will interfere with ventilation. In addition, performing routine blood tests including coagulation and arterial gases may be beneficial. However, most patients present as emergent cases, and there is therefore no time to perform an in-depth preoperative assessment.

In the setting of rigid bronchoscopy, general anesthesia is required and various techniques have been used, including spontaneous ventilation with manual assistance, jet ventilation, inhalation ventilation, and mechanical ventilation. In the case of an obstructed airway, jet ventilation carries an increased risk for barotrauma if expiration is obstructed. To address this potential complication, the Richard Wolf company has developed the Hemer rigid bronchoscope with a measuring tube connected to the bronchoscope lumen allowing measurement of inspiratory and expiratory pressures, as well as oxygen and carbon dioxide concentrations. In general, anesthesia is induced using a combination of a benzodiazepine, such as midazolam, and an opiate, such as remifentanil. Anesthesia is maintained using different techniques, frequently chosen based
on the experience of the anesthetist. These techniques include target-controlled infusion devices, simple infusion devices, and topping up according to the desired level of sedation. There is insufficient evidence to recommend one technique rather than another and the choice of anesthetic agent and mode of ventilation is often made after discussion between the anesthetists and endoscopists at individual centers. Irrespective of the technique used, it is imperative that members of the team have a good working relationship, because both the anesthetist and endoscopist need to work in unison during the procedure.52,53

SUMMARY

The rigid bronchoscope is the instrument of choice in most bronchoscopic therapeutic procedures. The rigid bronchoscope is not only a tool to visualize the airway but also a therapeutic instrument in itself or in association with other endoscopic techniques. Most of the scientific associations (European Respiratory Society, American Thoracic Society, American College of Chest Physicians) agree on this point. Rigid bronchoscopy requires training and a dedicated facility or easy access to an operating room with anesthetic support. Moreover, rigid bronchoscopy is mandatory in airway stenting when using silicone stents, which still represent the gold standard. Interventional bronchoscopy is a minimally invasive option in a variety of cases, and can occasionally represent a bridge to definitive surgical management. If there are surgical contraindications, endoscopic techniques are acceptable definitive palliation interventions.

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