Volume 18, No 1, January-March 2012

REVIEW ARTICLE

RIGID BRONCHOSCOPY

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ABSTRACT:

Complex airway diseases often represent a therapeutic challenge and require a multidisciplinary approach involving interventional pulmonologists and thoracic surgeons. While surgery is often the preferred definitive modality, advances in bronchoscopic techniques have led to substantial improvements in patient symptoms and long-term quality of life using minimally invasive techniques generally safe when performed by experienced proceduralists. Endobronchial laser therapy, cryotherapy, electrocautery or argon plasma coagulation and photodynamic therapy have been used successfully.

Despite new technologies, the rigid bronchoscopy remains the method of choice for the treatment of both benign and malignant central airway obstruction. It allows rapid and safe dilation, mechanical debulking, foreign body removal and silicone stent placement. Its limitation is represented by peripheral or upper lobes lesions, which are not assessable with the rigid tube but significant technological advances allow for effective treatments using the flexible bronchoscope. Rigid and flexible bronchoscopes should not be opposed and are fully complimentary.

Keywords : interventional pulmonology, interventional bronchoscopy, bronchoscopy, rigid bronchoscopy, flexible bronchoscopy, laser, airway stenting, silicone stent, foreign body, central airway obstruction, lung cancer, airway stenosis, tracheal stenosis, lung transplantation, bronchial stenosis, airway compression.

Historical background

Rigid and therapeutic bronchoscopy was born in 1895 in Fribourg (Germany) when Gustav Killian removed a pork bone from the bronchus of a farmer using a rigid esophagoscope. His efforts were greatly aided by discovery of the anaesthetizing effect of locally applied cocaine. Subsequently, across 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 treated endobronchial complications of tuberculosis, which was the main airway disease during the first half on the twentieth century. He also performed the first endoluminal mechanical resections of endobronchial tumours. Other significant advances were the optical telescope by Broyles and the solid rod lens optical system by Hopkins[1]. Modern bronchoscopy benefited from the works of Shigeto Ikeda, a Japanese pulmonologist, who developed flexible bronchoscopy using optic fibers[1], which radically transformed the diagnostic approach to lung cancer. Rigid bronchoscopy became obsolete and was virtually abandoned in favor of flexible bronchoscopy. The flexible bronchoscope has become the diagnostic instrument of choice for visualisation of the bronchial tree during the last 30 years as it is less invasive, does not require a general anesthetic and provides superior visualisation of smaller peripheral airways. However, some European physicians continued to use the rigid system for the treatment of airway diseases, among them was the father of the modern therapeutic bronchoscopy, Jean-François Dumon, unanimously regarded as a pioneer in the field of interventional pulmonary medicine. He was one of the first bronchoscopists [2-5] to use laser therapy in the airway and standardized its utilization[6,7]. Another major contribution was the invention of a dedicated silicone stent for the trachea and bronchi [8]. Before the era of Dumon stents, the only available option for re-establishing patency of the trachea post-operatively was the Montgomery T-tube, which required a tracheostomy for placement[9].

Rigid bronchoscopy equipment[10]

The modern rigid bronchoscope is essentially a straight, hollow stainless steel tube and has not changed much from the equipment developed by Jackson. It comes in various lengths and diameters ranging from 5 mm to 13.5 mm as determined by the manufacturer. The barrel wall is 2–3 mm thick and the internal diameter is uniform throughout. The distal ends of most bronchoscopes are bevelled, allowing atraumatic passage through the vocal

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cords. The bevel can also be used to ''core'' out tumor and to ''corkscrew'' the bronchoscope through tight stenoses[10,11]. Slits in the distal wall of the bronchoscope allow contralateral ventilation during intubation of a main bronchus. The tracheoscope is shorter in length compared with 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 manufactured by EFER Endoscopy (La Ciotat, France) has a universal proximal head that can be connected to bronchoscope barrels of various lengths and diameters that are also colour coded (figure I). Other manufacturers of rigid bronchoscopy equipment include Richard Wolf (Knittlingen, Germany) and Karl Storz (Tuttlingen, Germany) (figure II). 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 either looks down the eyepiece of the telescope, or a charge-coupled device chip video camera is connected to the eyepiece for visualisation on a monitor, also allowing recording of procedures. Before the development of the flexible bronchoscope, angled telescopes were needed on order to view all bronchial subdivisions but currently most bronchoscopists would rather pass a flexible bronchoscope via the barrel of the rigid bronchoscope for this purpose. Ventilation during rigid bronchoscopy can be achieved either via conventional or jet 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. 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[10]

Rigid bronchoscopy is usually performed under general anesthesia. After induction of anesthesia the patient's head is partially extended and the bronchoscope is introduced in the midline with the bevel anterior (figure III). 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 through 90° to allow atraumatic passage through the vocal cords. Once the trachea is entered, the bronchoscope is rotated back through 90° and advanced to the lower trachea. To enter one of the bronchial systems the patient's head is rotated towards the contralateral shoulder. When using the tracheoscope, thinner diameter bronchoscope barrels can be inserted through the tracheoscope. There is therefore no need to remove the latter or to reintubate the patient. A flexible bronchoscope can also be passed via the level of the rigid bronchoscope to allow inspection of and procedures in distal airways. 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: advantages and indications

The rigid bronchoscope is an invaluable tool in interventional bronchoscopy[12-15].
It allows, with maximal safety and under general anesthesia, adequate ventilation of the patient through a side port, efficient suctioning of blood, secretions, pus and smoke allowed by large suction catheters, and the use of various instruments (laser probes, cryoprobes, rigid forceps, etc.) alongside the telescope of [10].

The rigid bronchoscope is the instrument of choice in case of acute respiratory failure secondary to endoluminal obstruction as it allows for a rapid procedure while maintaining airway patency and adequate ventilation. Due to obvious anatomic limitations, however, its use is not suitable for upper lobe diseases. Rigid bronchoscopy is required for silicone stent placement using a dedicated rigid loading system.

Treatment of central airway obstruction with the exclusive use of a flexible bronchoscope is not generally recommended, particularly in the case of tracheal lesions. Its small working channel may be not sufficient to clear in massive bleeding. Biopsy forceps have a small diameter that only allow for removal of small tumoral fragments leading to long and fastidious procedures, limiting its use in case of respiratory emergencies[1]. Thus, techniques using metallic snares or baskets have been developed in order to remove larger pieces of tumors or foreign bodies[10]. Rigid and flexible bronchoscopy remain complementary techniques, and most often used concurrently during these procedures. Flexible bronchoscopy is an important tool with easy maneuverability that allows exploration and clearing the peripheral airways and upper lobe obstruction.

Foreign bodies (FB)[16]

The use of rigid bronchoscopy versus flexible bronchoscopy has been debated widely in the literature [17, 18]. The rigid bronchoscope provides excellent access to the subglottic airways and coaxial passage of multiple instruments, including grasping forceps. Optical forceps allow direct visualisation of the FB and optically guided grasping. Alternatively, a rigid telescope and a forceps can be used coaxially through the bronchoscope (figure IV). For smooth and rounded FBs, the key is to grip the largest volume of the FB. In this setting, the smooth forceps (foreign body forceps) are preferred to the sharp alligator forceps. The forceps' cups are opened maximally and the forceps is advanced under visual control using great 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 two or three fragments may help extraction. Heavy FBs, such as metallic FBs, tend to move distally due to gravity; in this setting, it may be helpful to place the patient in the Trendelenburg position. Once the FB is removed, the trachea is reintubated with the rigid bronchoscope and the airways are carefully re-examined, ideally with a fibreoptic bronchoscope passed through the rigid tube, to rule out another FB or residual fragments[19].

1-Silicone stent placement

Any endoluminal pathology 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 established [20]:

1- Extrinsic compression from tumours 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 (e.g. stump dehiscences or tracheoesophageal fistulas)

Endoluminally growing tumours 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 as stents may be harmful in the long run, even if early benefit is often noted[21]. In general, only removable stents should be used for these indications until a multidisciplinary team has determined inoperability[21].

Airway stents are generally divided into two types: the silicone stents and the metallic stents[21]. The Dumon stent (Tracheobronxane®, Novatech, La Ciotat, France) has a simple design consisting of a silicone tube with small studs on the external surface to reduce migration[8]. They have become, de facto, the gold standard for the treatment of benign and malignant stenoses over the past 10 years[21]. There are 2 specific designs: straight and Y-shaped (for disease involving the carina) [22]. Stents are available in various lengths and diameters to accommodate both pediatric [23] and adult anatomy. For irregularly shaped stenoses i.e. those with marked reduced central airway caliber as compared to the extremities, specialized hourglass-shaped stents are available [24]. Ideally, Dumon stents have to be inserted through a dedicated rigid bronchoscope (figure V). A Dumon stent can be repositioned, removed and replaced at any time with ease using standard grabbing rigid forceps.

2-Malignant airway stenosis

More than 30% of bronchial carcinomas present as a central airway obstruction[25]. Such obstructions may lead to specific complications that include reduced survival and decreased quality of life [26]. Given that oncologic treatments do not generally result in prompt improvements in patients' symptoms,[27, 28], endoscopic treatments are necessary adjuncts to the tailored management of the patients at all the 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 [29]. Airway involvement can be intrinsic, extrinsic compression or mixed[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 one is coagulation and devascularization of the tumor, the second is the mechanical coring and the third is coagulation of the tumoral base (Figure VI). This technique is called laser, or electrocautery, or argon plasma assisted mechanical debulking. Extrinsic compression without intra-luminal disease is readily

treated with dilatation followed by stenting. Mixed (intrinsic and extrinsic) obstruction treatment is usually multi-modality with debulking and stent insertion. Usually, benefits noted after successful bronchoscopic treatment of obstruction last for 2 to 3 months[30]. Benefit duration after stent placement is generally reported to be around 4 months before tumoral stent overgrowth [31], but this duration can be increased with the use of effective oncologic treatments (i.e. chemo- and/or radiotherapy) [32].
Other indications for endobronchial treatment include endobronchial metastases (e.g. esophageal, thyroid, renal cell carcinoma, colon and melanoma) or alternatively low grade primary tumors (e.g. adenoid cystic carcinomas, typical or atypical carcinoids).

4- Benign airway stenosis

4-1: *Post intubation or post-tracheostomy tracheal stenosis (PITTS)*
Despite the lower incidence of post-intubation or post-tracheostomy tracheal stenosis (PITTS), management of such conditions remains challenging. Indeed, 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 contra-indications to surgery [33].
One can divide PITTS into two different types: the web-like PITTS (disease of the tracheal mucosa sparing the cartilaginous rings) and the complex PITTS (involving deterioration of the cartilaginous support)[34]. The former is generally successfully treated by radial mucosal incisions followed by mechanical dilation [35]. The rate of success is close to 90%, in one to three sessions [36]. For the complex PITTS, mechanical dilation alone is most of the time not sufficient [34]. In case of surgical contra-indication, the next step would be the placement of a stent in order to maintain the long term patency of the tracheal lumen and prevent recurrence [34].

The choice of the stent is important. Self Expandable Metallic Stents (SEMS) have shown to make potentially operable PITTS inoperable because of the severe complications associated with the technique [37]. These facts prompted the FDA to publish recommendations to limit the use of SEMS in benign tracheal stenosis [38]. 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 one year) vary from 40% when the stent is placed for 6 months up to 70% when the stent remains in place for 18 months [34, 36, 39, 40]. One should also take into account the fact that silicone stents require surveillance and may present complications like migrations, granulations, and/or mucus obstructions that can affect the quality of life of the patients [41]. Migration is probably the most challenging complication in this indication, with a frequency ranging from 11 to 17.5% [33], especially when the stenosis is close to the vocal cords. This can be reduced by the use of a dedicated hourglass silicone stent [24] or by external fixation [42, 43].

4-2: Bronchial stenosis following lung transplantation
Improvement in surgical techniques, immunosuppressive regimen and post-operative care have resulted in markedly improved clinical outcomes, as airway complication rates have decreased, presently ranging from 5 to 30% with an associated mortality rate of 2-3%[44-49].
Several endoscopic interventions may allow effective management of LT-related airway complications. Such procedures include cryoablation, laser photoresection, balloon bronchoplasty, electrocautery, brachytherapy, airway dilation using rigid bronchoscopy and stent placement [50]. Stent placement is usually considered for bronchomalacia, bronchial stenosis, combined stenosis and malacia, or bronchial dehiscence. Stent placement can result in mucosal ischemia and re-stenosis is a common finding. It is advisable to select a stent that can be removed if necessary without causing further tissue damage. Recently, our group has published a retrospective study on Dumon stent placement in anastomotic stenosis after lung transplantation[51]. These stents could be removed definitively in 70% of the patients without further recurrence[51].

CONCLUSION

The rigid bronchoscope is the instrument of choice in the vast majority of bronchoscopic therapeutic procedures. Indeed, the rigid bronchoscope is not only a way to visualize the airway but a therapeutic tool in itself or in association with other endoscopic techniques. Most of the scientific associations (ERS, ATS, ACCP) agree on this point. Rigid bronchoscopy requires training and a dedicated facility or an 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. In case of surgical contra-indications, endoscopic techniques are acceptable definitive palliation interventions.

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Volume 18, No 1, January-March 2012

Figure I: THE EFER RIGID BRONCHOSCOPE

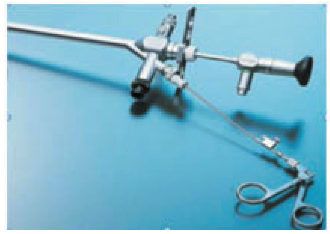

Figure II: THE STORZ RIGID BRONCHOSCOPE

Figure III: RIGID BRONCHOSCOPY INTUBATION

Figure IV: FOREIGN BODY REMOVAL USING THE RIGID BRONCHOSCOPE

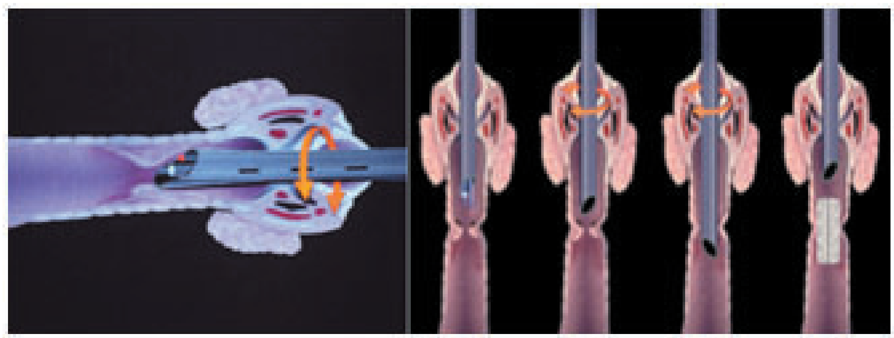

Figure V: SILICONE STENT PLACEMENT WITH THE RIGID BRONCHOSCOPE

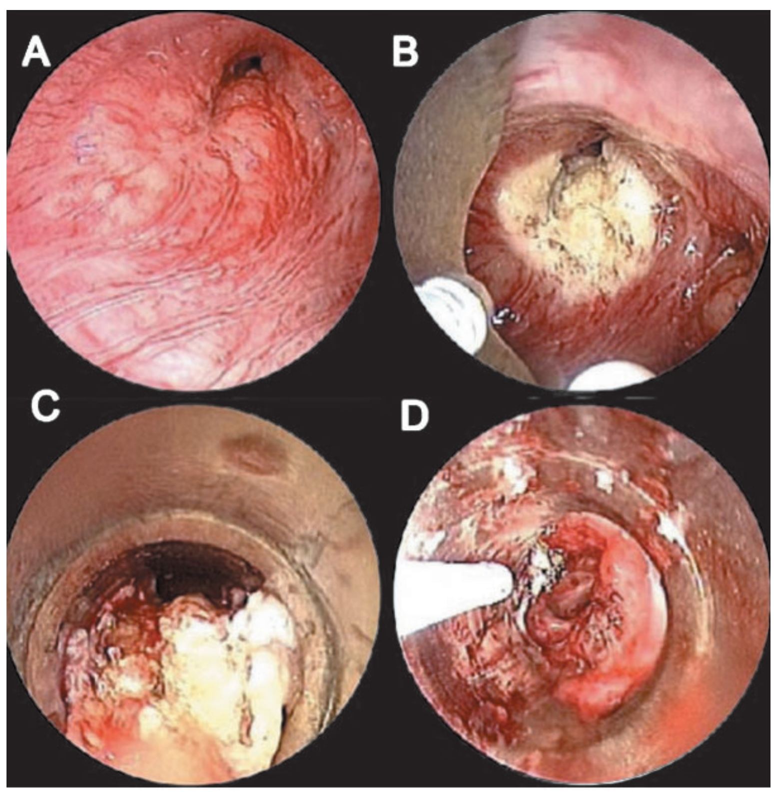

Figure VI: THE VARIOUS STAGES OF LASER ASSISTED MECHANICAL DEBULKING:

A: An adenocarcinoma obstructing the bronchus intermedius ;

B: Coagulation of the lesion (blanching effect);

C: Mechanical resection using the bevel of the rigid bronchoscope;

D: carbonisation of the residual tumour.