4 Rigid Bronchoscopy

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Introduction and History

Bronchoscopy is the invasive procedure most commonly indicated to diagnose and treat pulmonary problems. There are two kinds of bronchoscopes: the flexible bronchoscope (FB) and the rigid bronchoscope (RB). The first one is the most utilized in clinical practice. However, the rigid bronchoscope is a very important instrument for the diagnosis and treatment of many pulmonary disorders and has been applied to the airway for many decades.

The interest on reviewing the airway goes back to 1823, when Horace Green introduced first a sponge and then a rubber catheter into the bronchi, applying silver nitrate to burn lesions located at the level of the larynx and trachea. Later, Joseph O'Dwyer introduced a tube to release adhesions of the lower airways caused by diphtheria, and he also constructed a thin-walled tube to assist in the removal of foreign bodies.

The rigid bronchoscope was introduced by Gustav Killian (Germany) in 1897, for the extraction of a foreign object (a small piece of a pig bone) from a 63-year old man, becoming the father of bronchoscopy. For the procedure, Killian used an esophagoscope and rigid forceps [1]. Chevalier Jackson, from Philadelphia, Pennsylvania (USA), made popular this new bronchoscopic technique and developed the most commonly used rigid bronchoscope. His idea of placing a small light in the distal part of the endoscope revolutionized the endoscopist's ability to examine the airways. In 1916 he established bronchoesophagology departments in five hospitals in Philadelphia, training many well-known bronchoesophagology professionals [2, 3].

During more than 70 years, the rigid bronchoscope or open tube was the only available instrument to review the airway. At first, it was mainly used to remove foreign bodies or dilate strictures, but later new applications were described: aspiration of secretions, hemoptysis treatment, biopsies, etc.

Shigeto Ikeda's flexible bronchoscope (FB) development in the 1960s [4] has been the most significant advance in the area of bronchoscopy and has changed the practice to our days, allowing the pulmonology physicians to develop ability in performing flexible bronchoscopy and also gave place to the introduction of new technologies specifically designed to apply with FB.

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Shortly after its invention, the FB almost replaced the RB in the clinical practice. However, the rigid bronchoscope is still a very important instrument in the study and treatment of airway disorders.

RB and flexible bronchoscope complement each other in many indications, and there is no reason to see their application in opposite terms, since each instrument has strengths and limitations. In this chapter, we will review our experience on RB, along with a complete discussion on indications and contraindications.

Overview of RB

The RB is a stainless steel open tube with variable lengths and widths. It has a distal end, beveled and smooth, and a proximal end that can be adapted to a metallic universal head with several side ports. The distal end is used to lift the epiglottis during intubation and is also very useful to dilate strictures and to "core" tumors. Lateral openings or fenestrations are present to allow contralateral lung ventilation while working.

The RB is the preferred instrument for endoscopic resections. The rigid tube is the only device that allows a complete control on the airway, assuring proper oxygenation and ventilation while performing, for instance, a laser resection. Aspiration of blood, secretions, and smokes can be easily achieved at the same time that an excellent view of the central airway is depicted.

One of its main strengths is the ability to confront serious hemorrhagic accidents or airway obstruction from various etiologies: benign or malignant conditions, foreign bodies, mucus plugs, etc. Although unusual, massive hemorrhages can occur even in routine fibrobronchoscopies. The RB allows the application of pressure on the hemorrhagic area until hemostasis occurs, giving sufficient time to apply other therapeutic modalities, which can bring a definitive solution to the problem. It is also particularly useful in the pediatric population. Children airway diameter is very small, and it is preferable to use a hollow tube in order to allow spontaneous breathing or assisted ventilation. The FB blocks the airway, and the patient has to breathe around it, increasing significantly the airway resistance and work of breathing, difficulting procedures. The RB, in turn, allows the patient to breathe through it, favoring spontaneous breathing and mechanical ventilation while performing the procedure.

The rigid bronchoscope has undergone modifications over time, particularly after laser resection and stent placement became regular indications for different airway conditions. The most used brand names today are Efer(R), Storz(R), and Wolf (R).

Innovations

The first rigid bronchoscope for laser application was designed by Jean François Dumon (Fig. 4.1), from Marseille, France, for the brand Wolf. In contrast to other rigid bronchoscopes, the Wolf system has two lateral ports (one for the laser fiber and the other one for the suction catheter) and a rotating ventilation connector that allows assisted ventilation without interrupting the treatment. All ports can be occluded to allow closed

Fig. 4.1 Dr. JF Dumon

circuit ventilation. Based on this experience, the Dumon-Harrell (Efer) universal rigid bronchoscope was later developed; it associated modifications already present in the Wolf system with other advantages, such as the possibility of using a series of 11 interchangeable tubes with increasing diameters available in two different lengths: the short tubes (Fig. 4.2) for endotracheal treatments, with no side orifices (diminishing the air lost in the trachea), and the long tubes for endobronchial treatments, with lateral orifices that allow an adequate ventilation even when the bronchoscope is placed in a peripheral bronchus. Internal and external diameters are color coded on each tube (from 3.5 to 10 mm internal diameter and from 4 to 12 mm external diameter). Available tubes for pediatric use have an internal diameter from 3 to 5 mm and 20 cm in length.

The head of the rigid bronchoscope can be adapted to the desired tube, according to the different needs (Figs. 4.3 and 4.4).

The Dumon-Harrell rigid bronchoscope comes with a separate deployment system for the silicon (Dumon) prosthesis.

Another Dumon-Harrell system innovation is the fact that it is possible to lift the superior part of the lateral door, allowing the aspiration of large tumor fragments without modifying the position of the suction catheter. The securing caps are made of Silastic, with one or several

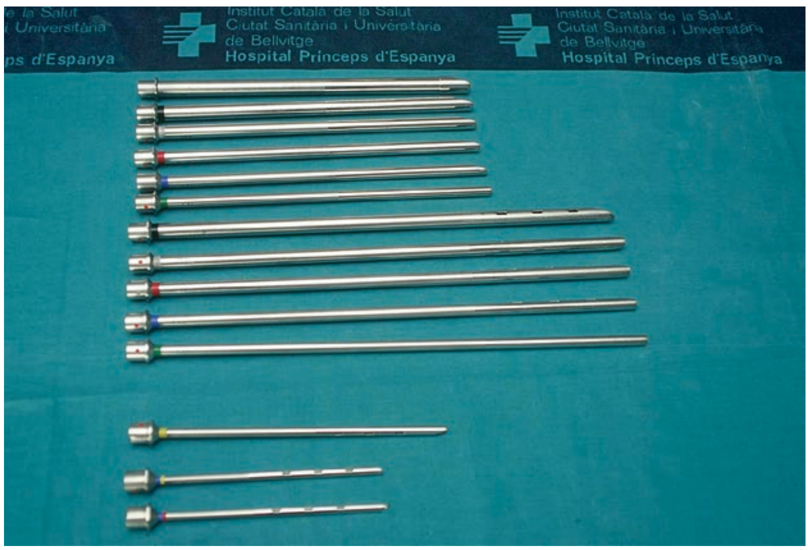

Fig. 4.2 Dumon's rigid bronchoscope

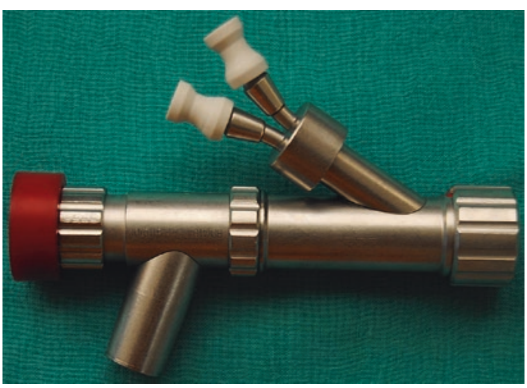

Fig. 4.3 Universal head of the rigid bronchoscope

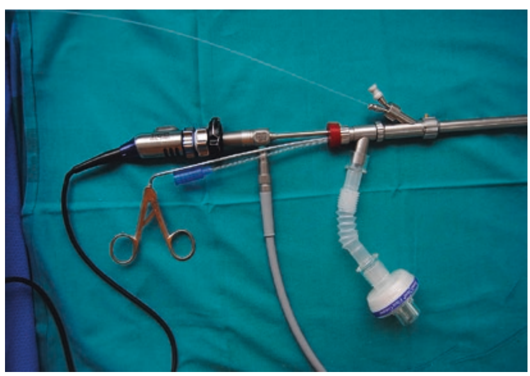

Fig. 4.4 Rigid bronchoscope with ancillary tools and connection for ventilation

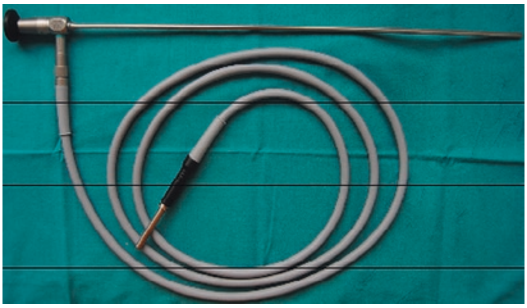

Fig. 4.5 Rigid telescope (optic)

orifices of different sizes. These caps are much more solid than the usual rubber ones, allowing a more hermetic closure, optimizing ventilation.

The rigid optics offer direct 0° vision (Fig. 4.5); they come in three diameters, 3.5, 5.5, and 7 mm; and they are not fixed. There is also a smaller optics for pediatric use. These instruments easily slide through the Silastic caps and can be moved back and forth according to need. It is a very useful feature to avoid sudden movements that can injure the airway. The rigid optic can be pulled back to avoid midst or loss of visualization due to blood or detritus. The rigid optic, suction catheter, and laser fiber are independent inside the rigid tube, making handling easier.

The most comfortable position when applying laser is placing the tip of the laser fiber advanced within the airway, the suction catheter located slightly back to the laser tip, and the rigid optic further back from the working field (Fig. 4.6). The independence of these elements allows modifying at any time their position according to the intervention needs.

The RB has been designed to present a universal character; in other words, to adapt to multiple endoscopic situations. In addition to laser application settings described above, this instrument can take other configurations: all or some of the entrance ports can be used (from one to three), open or closed ventilation circuit (for "jet ventilation," manually assisted ventilation, or spontaneous ventilation), and use of short or long tubes and adult or pediatric tubes, allowing diagnostic and/or therapeutic procedures on practically any group of patients.

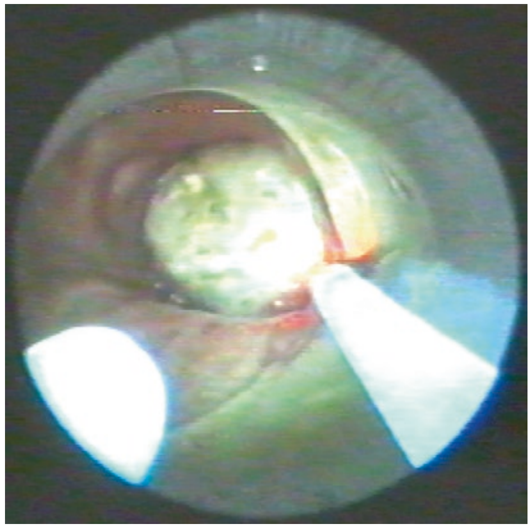

Fig. 4.6 Correct position of the suction catheter and laser fiber into the RB. It is important to always see the tip of the bronchoscope during the procedure

The Storz rigid bronchoscope was designed by Shapshay from Boston, USA. It is specially manufactured for jet ventilation, and for this reason it has a fixed port designed to serve this purpose. It is available in 10 mm internal diameter size (12 mm external diameter), presenting also a connection for ventilation and two additional ports [5].

A recently introduced rigid bronchoscope, called rigid integrated bronchoscope developed by Wolf, presents separate channels for optics and instruments and integrates the operator head with the camera. It has also an irrigation port to wash the distal lens. It has the advantage of increasing the working space and thus improves manipulation within the bronchoscope. However, the vision is limited since the camera does not go further distal to the end of the rigid bronchoscope.

It is clear that the RB, although keeping its original basic shape, has suffered several modifications to adapt to specialized procedures, like laser application, prosthesis placements, and dilatation of tracheobronchial strictures. The RB allows flexible bronchoscopes to get through it, taking advantage of both instruments at the same time.

Ancillary Equipment

Suction catheters: they play a very important role during procedures. In addition to suction of blood, smokes, and debris, they are useful in palpating lesions to give an idea on consistency. They are also used to instill medications such as saline, epinephrine, and lidocaine. It is recommended that they do not exceed 3 mm in diameter and are made of rigid transparent material. In that way the laser beam will not burn them, and they will not collapse during suction.

Other ancillary instruments that should be available are foreign body rigid forceps (used to retrieve different elements from the airway and to adjust position of silicone stents), scissors, scalpel, balloons, mechanical dilators, endoscopic resectors, prostheses, and laser equipment, most of them designed by Dumon (Fig. 4.7).

The capability of project images is very important as well. That serves various purposes: it allows all the team to follow the procedure in detail and anticipate steps. It also permits recording the procedure, for both educational and documentation purposes.

Applications and Contraindications

RB's most important applications are therapeutic and include laser application, electrocautery, argon plasma coagulation or cryotherapy, dilatation of tracheobronchial stenosis using balloon dilatation or directly with the rigid tube, airway stent placement, and foreign body removal, particularly in children. Massive hemoptysis is also another therapeutic indication. Diagnostic applications are hemoptysis and the need for deep

Fig. 4.7 Ancillary equipment designed by Dr. Dumon

Table 4.1 Indications for rigid bronchoscopy

– Foreign body removal
– Hemoptysis
– Tracheobronchial stenosis
– Tracheobronchiomalacia
– Central airway obstruction
– Extrinsic compression
– Therapeutic procedures:
Stents
Laser
Electrocautery
Cryotherapy
Argon plasma coagulation
Dilatational balloons

Modified from Lamb and Beamis [6]

biopsies, better obtained with the rigid biopsy forceps (Table 4.1) [6].

There are not many absolute contraindications for the use of the rigid bronchoscope: unstable cardiovascular state, significant cardiac arrhythmias, severe hypoxemia that will not improve with the procedure, and cervical spine instability. The most important contraindication is lack of appropriately trained personnel [7].

Some clinical situations, however, must be considered as relative contraindications for RB: an unstable neck that makes unsafe the excessive mobilization during the bronchoscopy, microstomy, maxillofacial trauma, or other oral lesions that prevent an appropriate mouth opening to introduce the rigid tube and technical difficulties related with cervical ankylosis and severe kyphoscoliosis, among the most important ones.

Rigid Bronchoscopy Applications

Laser Bronchoscopy

Laser bronchoscopy application has diminished in the last years. Reasons include high cost of the equipment, lack of adequate training, need for RB in most of the cases, long procedure time, the absence of improvement in mortality when applied to malignant conditions (even though quality of life and survival definitely get better), and the insufficient number of patients in some centers. In addition to this, other therapeutic modalities such as electrocautery and argon plasma coagulation have become more popular given their availability, low cost, and similar good results.

However, the application of laser therapy through the RB has not been replaced in some indications, and it is still the technique offering the best results. RB laser resection is an important tool in treating central airway obstructions (benign or malignant) and provides an immediate reopening of the trachea or bronchus when stenotic lesions are found. Most of the treatments are performed with Nd-YAG laser (neodymium-doped yttrium alulminum garnet) or Nd-YAP laser (neodymium-doped yttrium aluminum phosphate). Diode laser is also equally useful and has become more popular given its lower cost.

In a published series about laser applications in malignant lesions, 1585 patients were treated with 2253 therapy sessions of Nd-YAG laser during a period of 11 years. More than 93% showed immediate good results. Complications included 18 hemorrhages, 6 pneumothoraxes, and 10 deaths [8].

Similar results have been published on low-grade malignant tumors that are unresectable or present in nonsurgical candidates for advanced age or severe cardiorespiratory insufficiency. In a prospective study of 19 patients that presented with carcinoid tumor and cylindroma with inoperability criteria, the use of laser was associated with an immediate symptomatic improvement following the treatment in 100% of the cases. Fifteen patients were free from disease during a follow-up time of average 20 months (from 6 to 50 months), and two patients died of unrelated causes at 21 and 6 months of treatment. Although low-grade malignant tumor recurrence is hard to predict, the use of laser is an excellent way to keep inoperable patients free from symptoms [9].

In a retrospective review on laser bronchoscopy application, laser resection was offered to 17 patients with inoperable lung carcinoma requiring mechanical ventilation secondary to acute respiratory failure. All of them received Nd-YAG laser treatment through a RB, with respiratory assistance (jet ventilation) at the operating room. A subgroup of seven patients could be weaned from mechanical ventilation and were able to receive other therapies showing an improved survival. The rest of the patients had tumoral extrinsic compression of the airway or submucosal growing of the tumor and had almost no benefit from laser application. They died on mechanical ventilation or after been extubated when the order "comfort measures only" was established. Survival improvement seen in the first group of patients ($p = 0.0038$) was associated with the presence of obstructive endobronchial tumor as the cause of respiratory insufficiency [10]. These results show that even those patients with acute respiratory failure due to obstructive lesions can be treated with laser bronchoscopy with good results.

Tracheobronchial Prosthesis

On the last years, tracheobronchial stenosis has received much interest from bronchoscopists due to the several available techniques to treat this problem. Endoscopic treatment of tracheobronchial stenosis can be achieved through balloon dilatation, stent placements, laser resection, and even with dilatation with the rigid bronchoscope.

Balloon dilatation can be done through a RB or through a fibrobronchoscope with a wide working channel. The balloons are designed for esophagus dilatation but are also used in the airway; angioplasty balloons can be used as well.

RB dilatation is performed by applying a smooth rotation to the rigid tube, simultaneously advancing, and passing through the stenotic area several times until a safe airway diameter is achieved. Laser resection can be applied before this dilatation if needed. All fibrous stenoses treated by mechanical dilatation have the tendency to recur, and repeated procedures are needed to keep the airway open. In addition, sometimes forceful maneuvers cause mucosal damage with more scar formation, and in the long term, they can worsen the stenosis. Thus, mechanical dilatation is only recommended to solve an acute situation and as a bridge to a more definitive treatment. Benign airway stenosis is discussed in detail in a dedicated chapter of this book.

Tracheobronchial prostheses can be indicated in benign or malignant airway stenosis [11].

Several types of prosthesis are available to use with both the RB and the flexible bronchoscope. Many of the autoexpandable metallic prostheses have been designed specially to allow placement with the flexible bronchoscope under fluoroscopic control. Airway prosthesis is discussed in detail someplace else in this book. However, we have to say that the RB is the only instrument suited for silicon prosthesis placement. We recommend the use of silicon prosthesis to treat most of the airway lesions, particularly benign conditions since metallic stents are associated with significant complications that have been recognized for many experts and made clear by the FDA during 2005, when it recommended against metallic stent application to airway benign conditions. (Available at www.fda.gov/cdrh/safety/072905-tracheal.html.)

Results on the application of the RB are presented in a study where this instrument was used under general anesthesia to insert silicone prostheses (Dumon) in 31 adult patients with more than 50% malignant airway obstruction. After laser resection, a stent was placed, and all patients presented immediate improvement in respiratory symptoms. All patients but three tolerated well the prostheses. Stents were placed in the trachea in 14 cases, right main bronchus 13, left main bronchus 8, and intermedius bronchus 3. Complications included migration in five patients, mucous obstruction in two patients, and hemoptysis in one patient [12].

We consider training in RB use crucial to any interventional pulmonologist. Regardless of the type of stent selected for a given treatment, expertise working with the RB will be needed at some point during the course of therapy. For instance, when a complication arises (i.e., migration, stent disruption) and the prosthesis needs to be removed or replaced, the best instrument to retrieve it is the RB. In addition, most of the prostheses placed via FB are very difficult to remove with fibrobronchoscope, requiring the

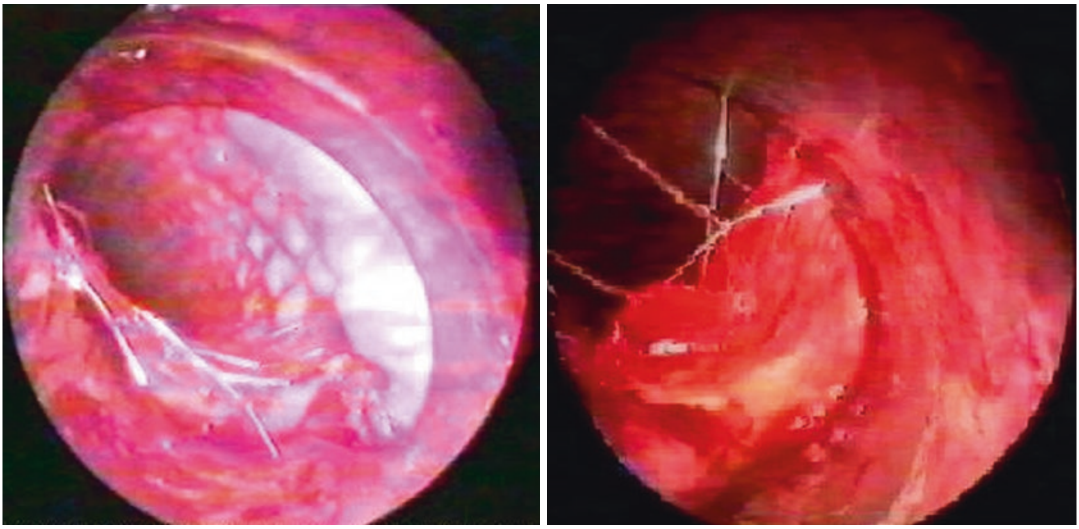

Fig. 4.8 Metallic prosthesis removal with the rigid bronchoscope

application of the RB to extract or adjust them. When metallic uncovered stents stay for a given period of time within the airway, they became embedded to the mucosa. In order to remove them, the beveled end of the RB should be placed between the metallic stent wall and the tracheal mucosa, and with soft rotating movements, the RB is advanced distally "dissecting" the stent from the airway wall until it is totally detached. Then it can be removed with a forceps (Fig. 4.8).

Likewise, the growth of tumor tissue through uncovered metallic stents requires RB and laser to relieve the obstruction, remove the prosthesis, and replace it in case of need. Training in RB is one of the most important skills that an interventionist has to learn and be proficient at and is a requisite when placing silicon (Dumon) prosthesis [12, 13]. Such training also involves the staff assisting and collaborating during the procedure: assisting nurse or scrub nurse, anesthesiologist, circulating assistant, etc.

Transbronchial Needle Aspiration

Transbronchial needle aspiration (TBNA) of subcarinal and paratracheal nodules was described in 1950. Wang, in 1978, reported a diagnostic sensibility of 90% for this technique when applied with the RB [14]. After the introduction of the FB during the 1960s, most of the bronchoscopists have been using this instrument to perform TBNA in lymph nodes located subcarinal and parahilar. Diagnostic sensibility for TBNA when performed with the FB has been reported as 80–89%, especially when the 19-gauge needle is used [15, 16].

The appearance of EBUS (endobronchial ultrasound) has completely changed the approach to lymph node sampling, and this technique has virtually replaced all blind procedures given the high diagnostic yield, particularly in mediastinal sampling [17]. However, in spite of EBUS generalized use, it can still be a place for blind TBNA applied both with the RB and the FB, particularly where EBUS is not available given its high cost.

A study published in 1996 described results on needle aspiration through the RB. Twenty-four procedures were performed in 24 patients using RB and a 2-cm long rigid needle, under general anesthesia and guided with computerized tomography. Samples taken were the tracheal wall ($n = 11$), main carina ($n = 3$), right secondary carina ($n = 3$), left principal bronchus ($n = 2$), and right principal bronchus ($n = 3$). The average amount of samples was 6 (from 1 to 19). An in situ cytopathologist immediately reviewed the samples to determine the number of samples needed. Diagnostic sensibility and specificity were 88% and 100%, respectively. TBNA resulted diagnostic in 18 patients. Findings helped in therapeutic decisions in 21 patients. There were no false positives during a follow-up period of 6 months. Three false negatives were present, and follow-up showed that these three patients ultimately had malignant lesions. There were no complications [18]. Those findings suggest that even though the technique has been improved by using EBUS or blind TBNA with the FB, the RB can have a role in the diagnostic of intrathoracic lymphadenopathies if no other method is available.

Rigid Bronchoscope in Other Treatments for Bronchial Obstruction

Laser treatments in tracheobronchial obstructions are effective but expensive. As a result, other therapeutic options have been developed and applied with good results. Electrocautery is broadly available, and results in airway resections are comparable to laser. Also, cryotherapy and argon plasma coagulation can be applied with RB.

Results on electrocautery application with the RB are depicted in a study that performed this procedure under general anesthesia in 29 patients with tracheobronchial obstruction, 24 of which had malignant conditions. In nine patients, stents were placed immediately after electrocoagulation. All patients but one presented immediate improvement of the symptoms, and an objective improvement in the pulmonary function was also observed in eight patients who had been tested with spirometry before surgery. There were neither intraoperative deaths nor complications [19]. Electrocautery can be also applied through the FB, but similar to laser applications, procedures are more time-consuming since the RB allows better vision, optimal suction, and the possibility to remove large tumoral pieces. Cryotherapy has been presented as an alternative therapy for obstructions. However, it is called a "slow" opening method since it lacks immediate effects. Initially, all treatments with cryotherapy were performed with RB, but more recently, the cryotherapy probes have been designed for application with the FB, and new modalities of cryotherapy are available, such as cryoextraction or cryoresection and also cryospray, that make this technique more versatile and can be applied as a fast method to open the airway.

Balloon dilatation can be applied both with the RB or FB.

Mechanical Debridement

Even though laser, electrocautery, cryotherapy, and argon plasma coagulation are useful coagulating during debridement of airway lesions, most of the obstructive tumors are generally extracted in a mechanical mode. In fact, all opening procedures involve the use of forceps. When performed with a FB, this procedure is invariably long and tedious, especially if large tumors are involved. The removal of big tumor pieces through the narrow channel of FB is very complicated, since the biggest pieces that can be extracted fits in a small biopsy forceps. It is obvious that a bigger channel such as the one of the RB will accomplish the same task in a much short period of time.

Most of the experienced bronchoscopists use laser only to coagulate the tumor, and when that is accomplished, dissect large tumoral pieces with the beveled rigid tube, (Figs. 4.9 and 4.10) obtaining a much efficient procedure [20]. Grillo et al. [21] affirm that the use of auxiliary methods like laser is not necessary to reopen the airway and only adds costs and risks to the procedure. However, their study on 56 patients whose tumors were removed only by mechanical means showed a 7% mortality associated to the treatment; considerately higher than when other methods are applied, including laser.

The RB itself acts as an airway dilatator and can achieve reopening of an obstruction in a shorter time than required by the FB. There is an important

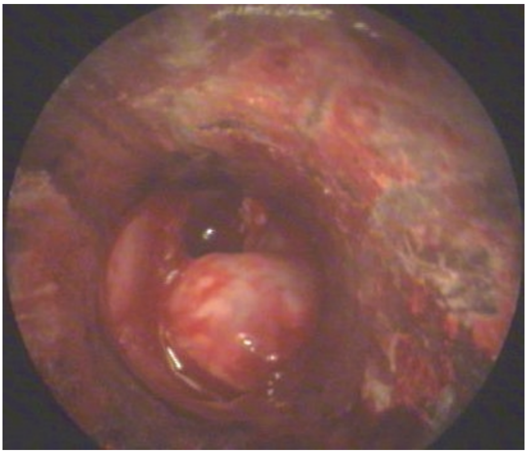

Fig. 4.9 Resection of a tumor with the beveled end of the rigid bronchoscope

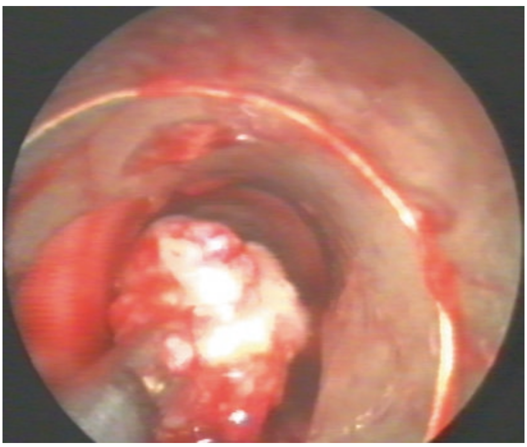

Fig. 4.10 Aspiration of a tumor piece with the rigid aspiration catheter

and statistically significant difference in the total number of sessions needed to permeabilize the airway with RB and FB; the RB requires only one session and the FB an average of two [22]. In fact, bronchoscopists who use only FB to extract tumors usually require several sessions. The theoretical advantage of the FB in opening peripheral airway obstructions is rarely needed, since these cases are infrequent and the need of reopening a distal airway as a palliative measure is questionable, unless postobstructive infection is present. In case of need, the FB can be more easily introduced through the RB (Fig. 4.11) and thus take advantage of the strengths of both instruments [23].

Fig. 4.11 Use of the flexible bronchoscope through the RB

Pediatric Rigid Bronchoscopy

In 1997 the Pediatric Bronchoscopy Group of the European Respiratory Society (ERS) presented the current pediatric bronchoscopy state in Europe. From the 125 contacted centers, it was informed that during the 12 months previous to the survey, 7446 bronchoscopies had been done on pediatric patients. About 4587 (61.6%) of these bronchoscopies were completed with FB and 2859 with RB. While 29 centers were utilizing both techniques, 17 centers were using only FB, and 5 centers just RB. Twenty-three centers were applying RB in the operating room, 7 centers in the intensive care unit, and 15 centers in a specially equipped room.

The most frequent indications included the following: persistent/recurrent pneumonia, wheezing refractory to medical treatment, persistent atelectasis, stridor, chronic cough, interstitial pneumonia, pulmonary tuberculosis, suspected foreign body, hemoptysis, and suspicion of pulmonary malformation, among others. The RB was completed under general anesthesia in 31 centers and under local anesthesia and intravenous sedation in 2. A bronchoalveolar lavage (BAL) was performed in 2231 children; 812 of them were immunodepressed. The utility of the diagnostic varied with the type of procedure. For centers using only FB, only RB, and the combination of both (FB + RB), diagnostic application was almost invariably superior when the use of FB and RB were combined, except for persistent/recurrent pneumonia [24].

Advantages of the RB in the pediatric population are mainly due to the fact that, in a small diameter airway, it is safer to use an instrument that does not produce increased resistance in the airway. The rigid scope provides complete airway control and, at the same time, the possibility of applying diagnostic or therapeutic interventions.

Tracheobronchial Dilatation

The RB has been used to perform tracheobronchial stenosis dilatation in children. The dilatation technique with an angioplasty catheter can be performed as follows: the catheter (6F, 8 mm diameter) is placed under direct vision with the RB, and balloon inflation is controlled with a manometer. Children so treated showed a significant improvement in the size of the intraoperatory lumen and an important postoperative clinical improvement, confirmed with endoscopies and radiographies. Recurrence of stenosis many times requires a repeated procedure until a more definitive therapy can be offered, or the natural increment of the airway diameter as the child grows up relieves the stenosis without the need of further procedures [25].

Other therapeutic options include the progressive dilatation using the rigid bronchoscope.

Foreign Body Removal

The RB is the instrument of choice to extract foreign objects in pediatric patients. It is a safe, effective, and lifesaving technique. The number of ancillary instruments such as forceps, baskets, etc. to use with the RB is important; almost every type of foreign body can be extracted. However, the flexible 1 mm channel bronchoscope can also be utilized for the same purpose [26]. Urologic instruments (like ureteral baskets and forceps) can go easily through this narrow 1-mm channel and capture big foreign bodies.

Nevertheless, it is recognized that the BR is still the best instrument to extract foreign bodies from the pediatric airway, and it is also preferred in adults. In a retrospective study in 60 adults presenting foreign body aspiration, the FB was successful in removal in 61% of cases, while the RB had a success rate of 96% [27]. In adults, however, the FB is frequently applied first to inspect and to try removal, and if it is not possible, then RB is considered [28].

Opinions about RB use on children, though, are divided. A prospective study evaluating the role of both instruments (rigid and flexible) showed that the predictive value of clinical and the radiologic findings in 83 children with foreign bodies in the airway were useful in deciding selection of RB or FB. The study concluded that the rigid bronchoscope must be used if any of the following clinical signs were present: asphyxia, a radiopaque foreign body present in the radiography, and the association of decreased air sounds along with obstructive overinflation in the chest radiograph. The FB can be used in the rest of the cases, and if during the procedure a foreign body is identified, RB must be utilized for its extraction. Application of the RB was always successful, except in one child who required a second session for the extraction of the foreign body. Postsurgical complications included laryngospasm ($n = 1$) and laryngeal edema ($n = 6$), and two of them required brief intubation. The extracted foreign bodies comprised of peanuts, vegetables, inert metals, bones and teeth, plastic pieces, and other inorganic objects [29]. The authors conclude that following this protocol was cost-effective, limiting the number of unsuccessful procedures and the use of RB. Many of the recommendations and conclusions of this study have been questioned, however. The study implies that the RB cannot examine the distal airway as good as the flexible bronchoscope. However, with the rigid bronchoscopes and smaller optics, the presence of foreign bodies can be detected as much as with a flexible bronchoscope. Procedures performed with the RB versus the FB are not more time-consuming at all; on the contrary, general anesthesia for RB can be completed with intravenous sedation, and the required time is comparable to the fibrobronchoscopy time. In addition to this, most of the foreign body removal performed with FB are also under general anesthesia, introducing the FB through an endotracheal tube, making manipulation cumbersome. Besides, children who were treated with RB did not have longer hospitalizations than children treated with FB [30]. In conclusion, we prefer the RB for foreign body retrieval in the pediatric population since it is safer and easier to do and the number of ancillary elements is such that virtually all foreign bodies can be removed in one session.

Rigid Bronchoscopy in Intensive Care Units

RB indications in the intensive care units (ICU) are limited. The most common are massive hemoptysis, large foreign bodies, obstructive lesions of the central airway, laser treatments, and prosthesis placement. All of these cases constitute relative indications, and the RB is, in practice, used only when the FB cannot fix the problem.

In the event of lung cancer patients ventilated for tumoral airway obstruction, the application of rigid laser bronchoscopy and airway stent according to need can result in a change of level of care allowing immediate discontinuation of mechanical ventilation as was published by Colt et al. [31].

Two important inconveniences in applying the RB in an ICU are the need of the bronchoscopist to be situated behind the patient and the difficulty of positioning the patient to easily insert the device. If the RB is indicated, it may be better to transfer the patient to the operating room to proceed.

Other Indications

The RB can be a lifesaving instrument in situations other than massive hemoptysis and foreign body removal.

In difficult tracheal intubations, the FB is used to guide the endotracheal tube to the trachea. Occasionally, when this technique fails, the RB may act as endotracheal tube.

Impacted mucus plugs, difficult to aspirate with the FB, can be easily extracted with the RB. This is especially useful in pediatric patients with cystic fibrosis, asthma, and post-operatory atelectasis.

Complications

Most of the complications arise from a poor RB insertion technique: laryngeal or vocal cord trauma, hypercapnia, hypoxemia, or hemodynamic instability. The bronchoscopist must not forget that he/she shares the airway control with the anesthetists and that oxygenation and ventilation have priority.

Complications associated to the use of RB include teeth, lips, gums, and throat lesions. Moderate laryngeal edema is very common but rarely produces relevant problems. Post-procedure throat and neck pain are frequent and usually last from 24 to 36 h. Vocal cord lesion is inversely related to the ability of the operator: on trained hands, it hardly occurs. Luxation of arytenoids may be also seen when a bad technique is used during intubation or when the procedure is executed with a poor local anesthesia or with an awake patient. A very infrequent and severe complication is rupture of the posterior tracheal wall. This requires surgical repair. Minimum or massive bleeding may occur during tumor resections. Most of the complications diminish as the bronchoscopist ability increases. Lack of training of the endoscopist or his/her assistants must be considered an absolute contraindication for the use of the RB [6, 32] (Table 4.2).

Drummond et al. published their 8 years of experience using the RB in a university hospital [33]. During this time 775 procedures were performed. The authors found that 13.4% of the patients experienced an associated complication. Most of them were minor complications. Patients presenting abnormal pulmonary function or basal hypoxemia and known cardiac disease and those with coagulation abnormalities (prolonged prothrombin time or thrombocytopenia) were more susceptible to complications than those without comorbid conditions. Preoperative risk increased when the following parameters were present:

Table 4.2 Complications

Hypoxemia
Cardiovascular instability
Tracheobronchial perforation
Esophageal perforation
Laryngeal edema
Vocal cord damage
Dental trauma
Pneumothorax
Severe bleeding
Mediastinal emphysema
Laryngospasm
Bronchospasm

- $PaO_2 < 55$ mmHg
- FEV1 < 50% of the predicted value
- Unstable angina or cardiac failure
- Severe arrhythmia
- Heart attack during the 6 months prior to the procedure
- Thrombocytopenia < to 50 × 10 [9]
- Abnormal prothrombin time

Patient presenting with any of these risk factors had a 37% rate of complication during rigid bronchoscopy. The group of patients with more complications presented malignant conditions involving the main carina. Also, those undergoing RB for airway obstruction had more chance to complicate. Only three deaths resulted from RB application. The cause of death was bleeding in two of the patients and respiratory insufficiency in the remaining one.

Complications were also frequent in the group of patients receiving RB to remove foreign bodies. The least complicated group was the one presenting benign conditions (benign tumor removal or benign stenosis treatment). In general, these patients showed less comorbidities.

One patient presented pneumothorax associated to the use of laser for airway resection. Other complications were those associated with anesthesia (hypoxemia, arrhythmia) and a dental piece rupture.

The experience published by this group reinforces the notion that patients must be carefully selected according to risk before performing RB. It also reminds us that the RB is a powerful therapeutic tool that can also cause damage.

The Procedure

When rigid bronchoscopy was introduced, it used to be performed in awake patients. Nowadays it would be an exception to proceed under those conditions. All patients we treat with RB are under general anesthesia, and they are carefully evaluated just as we do for any other surgical procedure. History taken should be detailed, noting all comorbid conditions and medications in use. Physical exam should focus on temporomandibular disorders, cervical spine mobility, and spine abnormalities. Minimum laboratory values must be obtained: coagulation profile, blood count, chemistry profile, acid-base status, and electrocardiogram. Usually patients already have images of the pulmonary lesions: chest radiograph and thoracic computerized tomography, which must be carefully reviewed before the procedure.

The patient and his/her family must receive a clear explanation about what will be done and sign informed consent.

The procedure can be performed in the bronchoscopy suite or the operating room, and a minimum of four persons are needed: bronchoscopist, anesthesiologist, assistant nurse, and a circulating assistant.

Preparation involves positioning the patient in a supine position, with a little pillow under the head, and application of topical anesthesia, lidocaine or tetracaine. Dental prosthesis should be removed and proceed to the inspection of teeth and gums. Additional local anesthesia is also flushed on the chords and high trachea with a syringe, under direct view via laryngoscopy. Then, an oxygen mask is placed for preoxygenation, and anesthetic induction and muscle relaxant medications are administered according to the usual practice.

A protection for the superior teeth is placed; it can be made of plastic or simply be a thick folded gauze that works as the rigid tube support and protects teeth and gums (Table 4.3).

Table 4.3 Requirements to perform RB

• Rigid bronchoscope and tracheoscope
• Light source
• Video monitor if available
• Rigid optic 0° angulation
• Ancillary equipment (alligator forceps, scissors, foreign body retrieval elements)
• Rigid suction catheter
• Ventilation system (jet ventilation, ventilation bag)
• Eye protection
• Mouth protection
• Flexible bronchoscope with additional light source and suction port
• Interventional application: stents and deployment systems, laser, electrocautery, dilatational balloons, etc., according to the procedure taking place

RB procedures have become a common practice, and the anesthetic techniques have evolved. All procedures are performed under general intravenous anesthesia. Muscular relaxation and paralysis can be avoided by administering appropriate sedation. This technique shortens the recovery period. We do not apply muscle relaxants since we have found that with appropriate sedation there is no need for administration of these agents. Many centers apply jet ventilation, but we prefer to perform all rigid procedures with manually assisted spontaneous ventilation. There is a special chapter in this book discussing in detail anesthesia in interventional procedures.

Once the equipment is prepared and the video camera system is connected, the conditions are given to initiate the procedure. The classic intubation technique requires considerable experience. It is performed with the RB and the rigid optic connected to the video system if available. The steps are the following (Fig. 4.12a–i):

1. The RB is held with a hand, adjusting the optic a little retracted in a way that the distal end of the RB is interiorly visible. The other hand is used to open the patient's mouth, advance the RB, and adjust the tongue. Then, with the index finger and thumb, the tip of the RB is held to direct it and to keep it in the middle line at the same time. When initiating the maneuvers, the instrument edge must be looking forward, and an appropriated protection for the teeth must be observed.
2. Keeping the instrument in the middle line, it is advanced slowly. Soft back-and-forth movements are simultaneously performed, in order to position it properly without causing any mouth injury and to get a better vision. The advance direction must be perpendicular to the operating table.
3. The RB should be thus advanced until the uvula is visible in the 6 o'clock position.
4. From there on, the advance angle is changed approximately 45° to the procedure table, and with soft rotation movements, the RB is introduced until the epiglottis is visible in the 12 o'clock position.
5. The RB tip is used then to softly lift the epiglottis, using the same rotation movements, and it is carefully crossed through until the vocal chords are visible.
6. Moving forward to immediately above the vocal chords, the RB is given a 90° clockwise turn, so the beveled edge is softly leaned on a vocal cord while turning and simultaneous advancing through the chords.
7. Once this is done, the trachea will be intubated, and the RB is again rotated 90° counterclockwise. The rigid tube is then introduced further. Then, the universal head is disconnected and reconnected to a bronchial tube, which is then inserted through the tracheal tube (Figs. 4.13 and 4.14).
8. Ventilation is connected and the therapeutic procedure can start. It is very important that the operator works in a comfortable position (Fig. 4.15).

It takes time and experience to be able to perform rigid intubation as described above. There are other techniques to place a rigid bronchoscope that are very useful during the training period. The first of them implies to intubate the patient with a conventional endotracheal tube and as a second step execute the intubation with the rigid tube, along the side of the ETT. This method has the advantage of giving the operator all the time needed to maneuver, since it does not require the patient to be in apnea like during the conventional

Fig. 4.12 Sequence of RB intubation. (**a**) Initial positioning, protection for teeth and tongue. (**b**) Slowly advancing with the RB perpendicular to the operation table until the uvula is in view. (**c**) Uvula. (**d**) Advancing from uvula, changing the angle to 45° until the epiglottis is in view. (**e**) Epiglottis. (**f**) The epiglottis is lifted changing to a more acute angle, until the arytenoid cartilages can be seen. (**g**) Once the arytenoids are in view, the RB should be positioned more horizontally until the chords are visible. (**h**) When vocal cords are in view, the RB is rotated 90° clockwise to place the beveled end leaning on the right vocal cord to protect it, while simultaneously advancing. Once in the trachea, the RB is rotated counterclockwise and advanced further. (**i**) Finally, ventilation is connected to oxygenate the patient for a while

Fig. 4.12 (continued)

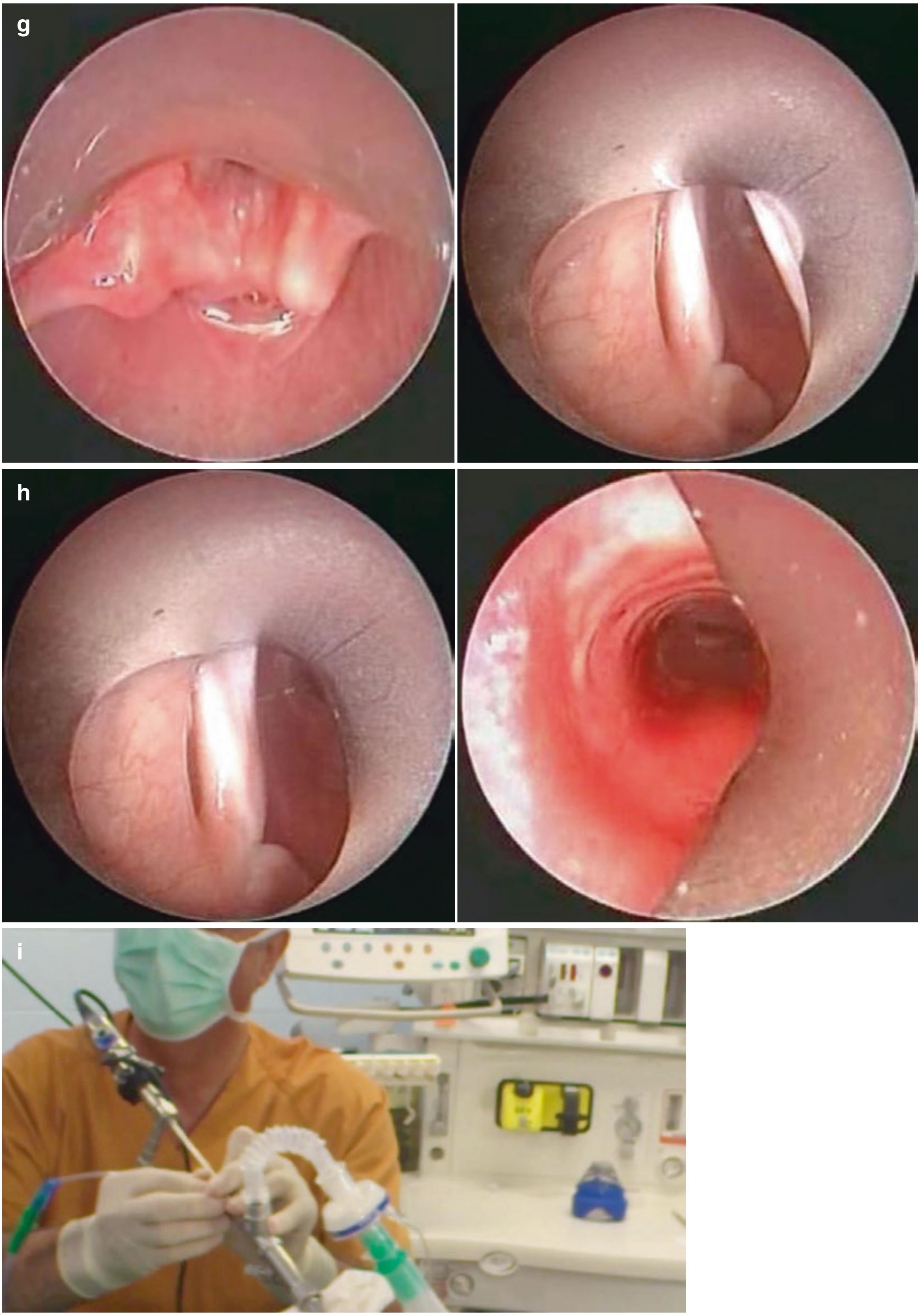

Fig. 4.12 (continued)

Fig. 4.13 Once the rigid tracheoscope is in the airway, the head of the RB is removed

Fig. 4.14 Head of the RB connected to a bronchial rigid tube. They are then introduced through the tracheal tube, and the procedure can start

Fig. 4.15 Comfortable position of the hands for manipulation of ancillary tools

technique but ventilated until the tubes are changed. The other alternative is to complete the intubation with the help of a laryngoscope.

This intubation is achieved observing the chords with a conventional laryngoscope. After lifting the epiglottis with it, the RB is inserted by the side of the mouth, directing it toward the larynx. Then, it is introduced between the vocal chords and softly rotated to keep it on the middle line without injuring the subglottic area. At this moment, the laryngoscope is removed, and the rigid optic is placed through the RB and advanced within the trachea under direct vision.

Intubation with RB through a tracheotomy is also possible. For this method, the rigid tube is introduced obliquely through the tracheotomy, previously numbed with local anesthetics. This maneuver must be carefully performed to avoid lesion of the posterior tracheal wall.

Some Conclusions

Before the FB introduction, the use of RB was almost limited to surgeons. During a British study, it was observed that, even though only 2% of the 39,564 bronchoscopies completed between 1974 and 1986 used RB, more than 90% were performed by surgeons. This work also noted that 81% of the bronchoscopists used FB, 9% of them were using both techniques, and an 8% used the FB through the RB [34].

In a review made by the American College of Chest Physicians, only 8% of the responding endoscopists were using RB [20]. The reasons are multiple, but some of the most important ones are that the FB is more available and easier to use than the RB that requires special training not given routinely during training programs.

This data ratifies a known fact: obtaining training on the RB technique is difficult, for several reasons. The first one is that its teaching is not part of the pulmonary specialist training as we discuss, while FB training is included. Besides, its use is generally associated with therapeutic procedures such as laser, stent placement, etc., and that requires specific technology not always available. Another inconvenience is that the technique is indeed difficult and requires full dedication to learn it. The number of procedures to become proficient varies from person to person. In addition, when proficiency is obtained, a number of regular procedures are required in order to maintain the ability and to get the interest of the involved team: nurses and anesthesiologists. In general, it is advisable that the person who is interested in learning interventionism follows a formal training with an expert, in a place where an adequate number of procedures are performed per year. Many experts agree that expertise on RB takes years and that courses and seminars (although indispensable to a complete learning) are not enough to initiate the individual practice without supervision. The ACCP guidelines published in 2003 recommended that a trainee should perform at least 20 procedures in a supervised setting to establish basic competency in patients with normal airways, and then he/she should perform ten procedures per year in order to maintain competency. They also recommended that program directors should decide whether or not the candidate is able to perform RB procedures without supervision. [35].

The ideal bronchoscopist should be able to perform both FB and RB, on pediatric and adult population. Given that lung cancer incidence continues rising and today the multimodality approach to treatment includes a pulmonary physician able to perform palliative procedures according to need, the RB will continue to be indicated. This instrument has unique features that make it irreplaceable, and it is also complementary to many other tools, particularly when treating central airway diseases. Though still RB is performed by a minority of physicians, there is an increased interest to train and maintain proficiency in rigid bronchoscopy, and we are sure that it will be more so in the future.

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