Flexible Bronchoscopy Training

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Introduction

Flexible bronchoscopy (FB) was introduced in the late 1960s, and it quickly became an integral part of the practice of pulmonary medicine in adults and children alike [1–3]. FB is a manual procedure and its success depends largely on the skills of the person who performs it. Although natural talent certainly helps, the ability to acquire (and perform) the skill depends in part on the way it is taught and on continuous practice.

Teaching is the transfer of knowledge, experience, and/or skill from one person to another; the way this transfer takes place constitutes the method of teaching. Historically, medicine (including the various procedures) was learnt through an apprenticeship. The apprentice would follow and observe the "Master," and it was the apprentice's responsibility to understand and not of the master to explain. The master would also decide for how long the apprenticeship would last and when the apprentice would be allowed to practice on his/her own.

The foundations of the modern teaching of procedures are attributed to William Stewart Halsted (the first Chief of Surgery at Johns Hopkins Hospital) who established the first formal surgical training. His approach was summarized in the concept of "See one, Do one, Teach one." The trainees were to observe a senior staff member doing a given procedure. The expectation was that after observing, the trainees would be able to perform the procedure on their own. Furthermore, they were expected to be able to teach others who had never done or observed one. Many of the pediatric bronchoscopists learnt according to this model. The trainees would initially observe an attending perform the bronchoscopy. They would then be allowed to hold the scope and navigate the easy parts of the airway (e.g., withdrawing the scope from the trachea), then the more challenging smaller airways until eventually they were allowed to perform the procedure on his/her own. During recent years, this model of learning has come into question and newer approaches have been proposed based on methods that are currently considered as more appropriate for adult learning [4–9].

As the procedure gained popularity and acceptance, the professional organizations such as American Thoracic Society (ATS), European Respiratory Society (ERS), and American College of Chest Physicians (ACCP) developed guidelines for its performance. Most of them focused on adult bronchoscopy (only two training guidelines have been specific to pediatrics). All the available documents have been largely limited to technical details on how the procedure should be performed but not on how it should be

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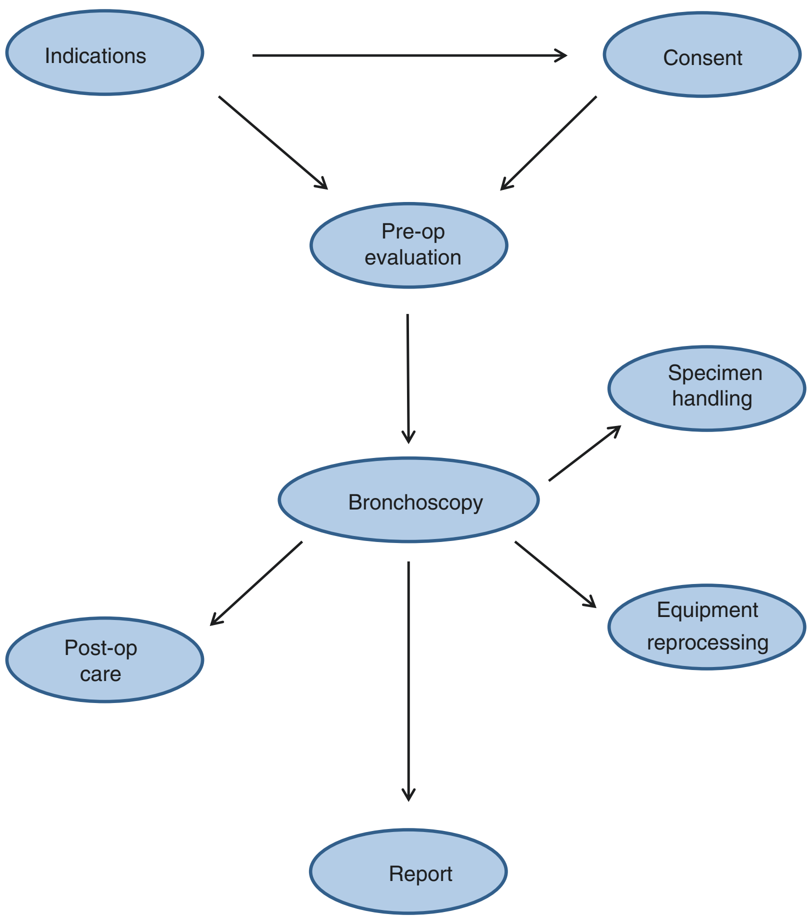
taught. Even less developed is the evaluation of the knowledge and skill of a bronchoscopist. There are no uniform criteria and methods to evaluate competency. The following chapter is focusing on the teaching of and training in flexible bronchoscopy of the pediatric pulmonary fellows. It reviews the literature as well as the author's personal and institutional experience. The chapter addresses three key questions: (1) What to teach, (2) how to teach it, and (3) how to assess the competency of the trainee.

Part 1. What to Teach?

The teaching of bronchoscopy consists of several elements (Fig. 14.1). The central one is of course to teach how to perform the actual procedure, that is, how to hold the bronchoscope and use its controls to navigate through the airways, as well as how to perform other procedures with it (e.g., bronchoalveolar lavage (BAL)) or through it (e.g., transbronchial biopsy (TBB) with the use of specific forceps). However, there are many equally important, although not as obvious, aspects that the bronchoscopist should master, including the following: (a) determining the indications for the procedure, (b) obtaining consent, (c) preparation of the patient and of the equipment for the procedure; (d) the care of the patient after the procedure, (e) the processing of the specimens that are obtained during the procedure, (f) the reprocessing of the equipment used in the procedure, and (g) the reporting of the findings of the procedure. Many of these elements are being discussed in detail in other chapters of this book and therefore in this chapter we focus primarily on the procedure, and how it can be

Fig. 14.1 The elements of bronchoscopy



taught. There is no universally accepted curriculum for the teaching of bronchoscopy, but there is a broad consensus as to what bronchoscopists should know before they start performing the procedure independently.

Why Is the Procedure Done?

In contrast with adult bronchoscopy that is geared more and more toward therapeutic applications, the pediatric bronchoscopy remains a primarily diagnostic procedure with a few, for the moment, therapeutic applications (Table 14.1). Several guidelines list a number of symptoms and/or conditions the patient has (e.g., unexplained wheezing, hemoptysis, etc.) as the main indications for the bronchoscopy [2]. Although the symptom is the reason the patient goes to the doctor, the decision to perform FB (versus any other diagnostic test) is based on the expectation that FB may reveal something that other diagnostic or therapeutic modalities cannot. Thus, one can categorize the reasons to perform FB as follows: (a) to determine the presence and severity of anatomical abnormalities (static and/or dynamic), (b) to obtain bronchoalveolar lavage fluid for cultures and other tests, (c) to verify the presence and determine the location of bleeding, and (d) surveillance. The latter is usually done for one or more of the following reasons: (1) detection of occult infection (e.g., many CF centers in other countries advocate annual surveillance bronchoscopies in patients with cystic fibrosis (CF) as part of their routine follow-up), (2) inspection (and biopsy) of a transplanted lung, and (3) evaluation of the condition of a patient with artificial airway(e.g., chronic tracheostomy).

The therapeutic applications of flexible bronchoscopy in pediatrics are very limited by the size and pathology of the pediatric patients. The size of the infant/pediatric airway does not allow the use of bronchoscopes with working channel that is large enough to accommodate specialized equipment such as endobronchial ultrasound (EBUS), lasers, and other therapeutic modalities. In addition, endobronchial lesions that are one of the most common indications for FB in adults are pretty rare in children.

Table 14.1 Indications for flexible bronchoscopy in infants and children

Diagnostic	Therapeutic
Determine the presence and severity of anatomical abnormalities	Persistent atelectasis
Abnormal breathing sounds (e.g., persistent stridor, persistent wheezing)	Foreign body retrieval (if rigid bronchoscopy is not available or if foreign body cannot be reached with the rigid bronchoscope)
Evaluation of suspected or known anatomical abnormality (e.g., tracheoesophageal fistula)	Difficult intubation
Suspected endobronchial lesions and/or foreign body	
Bronchoalveolar lavage (BAL) for:	
Cultures	
Cytology	
Lipid-Laden macrophages/ pepsin assay	
Alveolar proteinosis	
Determining site of bleeding	
Surveillance for	
Airway injury/repair (e.g., smoke inhalation injury)	
Cultures (e.g., in patients with cystic fibrosis)	
Transbronchial biopsies to rule out rejection of transplanted lungs	

The Airways

Flexible bronchoscopy is an exploration of the airways. It is obvious that one cannot determine whether a finding is abnormal without knowing how the normal looks like. Thus, it is imperative for the trainees to learn the normal anatomy of the airways first, then, its normal variants and finally the various abnormalities. Considering that when a patient with a certain airway abnormality may present is totally unpredictable, each program should develop its own library of slides and/or videos. Although the subject (i.e., anatomy) lends itself to the format of a lecture, it is known that listeners absorb only a fraction of what a speaker is presenting, and they remember even less. The airway anatomy can be best taught (and retained by the trainee) when it is presented in a clinical context. When possible, it is very important to correlate the bronchoscopy findings with radiographic findings, pulmonary function tests (PFTs) and clinical symptoms.

The airway abnormalities can be broadly divided into “structural” and "dynamic". The structural are fixed (e.g., complete tracheal rings and tracheal bronchus) and do not change significantly during the respiratory cycle, whereas the “dynamic” (e.g., tracheomalacia) vary significantly not only during the regular respiratory cycle but especially with changes in the intrathoracic pressure such as during crying or coughing. The primary objective of the diagnostic bronchoscopy is to find an abnormality that can explain the symptom, but it does not necessarily provide a diagnosis by itself. For example, presence of subglottic stenosis can explain persistent stridor but it does not reveal the cause of the stenosis (it could be idiopathic, or secondary to tracheal injury or a manifestation of granulomatous polyangiitis (a.k.a. Wegener’s granulomatosis). It is the association of the finding with the clinical history, radiographic, and/or laboratory findings that will lead to the actual diagnosis.

The Bronchoscope

Before performing the procedure, one should become familiar with the tools that are being used. In brief, there are three basic types of flexible bronchoscopes: the fiberoptic, the videobronchoscopes, and the hybrid. From the outside, all types look very similar consisting of the “body or handle” that is shaped as an elongated narrow inverse cone, and a long insertion tube (the “shaft”) that is the part that is actually entering the airways. The main difference between them is in the way the image is acquired and processed. In the fiberoptic bronchoscopes, the image is transmitted through glass fibers, directly to an eyepiece located on the top of the head. In contrast, the video- and hybrid-bronchoscopes require a processing unit in order to produce the image [10].

The Body: The wider part of the body is on top. In the pure fiberoptic scopes, the head consists of a round eyepiece with rings that allow focusing (Fig. 14.2). Special adapters also allow cameras to be attached to the eyepiece so one can take pictures or record a video. In the video and hybrid flexible bronchoscopes, the head is a box-like structure without eyepiece (Figs. 14.3 and 14.4). Instead, there are several buttons (in the front and on top of the head) that allow the taking of still pictures, “freeze-frame” and videos. The images are being instantaneously transmitted to a video processor and can be viewed on a video monitor. On the left, all bronchoscopes have a large cable that provides the connection with the light source, and with the video processing unit. In the back of the head, there is a horizontal lever that is articulated on the right side of the head and can move up and down. In the front of the body, there is a suction valve that is covered by a disposable adaptor with a port that connects with the suction tubing that on its other end it connects with an external source of negative pressure. By pressing on the valve, one can apply intermittent or continuous

Fig. 14.2 Flexible fiberoptic bronchoscope

Fig. 14.3 Diagram of a videobronchoscope (side view) with detail of its tip

suction. In the lower part of the body, there is a second valve that connects to the working channel. This valve allows the instillation of fluids (e.g., for bronchoalveolar lavage) and/or the inseryion of instruments (e.g., biopsy forceps). The older fiber-optic scopes had only valve that was serving both as suction and as working channel.

The Insertion Tube: The insertion tube consists of a light metal mesh tube covered by rubber-like material (Fig. 14.3). Inside, it contains several components: There is a channel that starts from the suction valve and runs through the entire length of the insertion tube to its tip, and it is used for suctioning. A second channel starts from the working channel valve, and it is used for instillation of fluid and for instrumentation. The two channels join each other at the lower part of the insertion tube. Thus, there is only one opening seen at the tip. This arrangement saves space, but it has the disadvantage that when an instrument (e.g., brush and forceps) is placed into the working channel it effectively blocks the suction (this is particularly true in the pediatric scopes whose channel is only 1.2 mm in diameter). On the two sides of the suction/instrument channel, there are two wires that are controlling the angulation of the tip of the scope. Below the suction/instrument channel, there is the image guide fiber bundle ("objective lens"). These fibers have to be precisely arranged at both ends of the bundle otherwise the image will be distorted. When they image fibers break the image appears to have dots. On the sides and slightly above the objective lens, there are the light guide fiber bundles that transmit light from the light source.

The diameter of the insertion tube varies from as little as 1.8 to 6.8 mm. The bigger bronchoscopes allow for a bigger channel that in turn

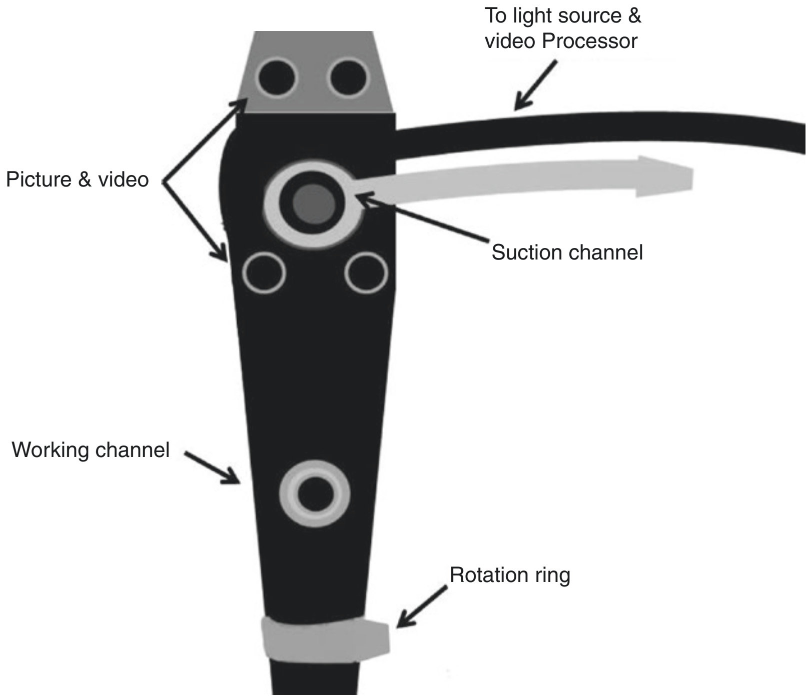


Fig. 14.4 Diagram of a videobronchoscope (front view)

allows the use of more complex instruments. The smallest ultrathin scopes (1.8 and 2.2 mm) do not have suction channels. The channel in all pediatric scopes that are <4 mm in diameter, is 1.2 mm. A 4.0 mm scope can have a 2.0 mm channel, whereas the biggest scopes (>5.5 mm in diameter) can have a channel up to 3.2 mm in diameter. The working length of the insertion tube is 600 mm regardless of the diameter.

Light Source: To be functional, the bronchoscope needs to have a light source to illuminate the lumen that is being examined, and a mechanism to transmit the image to the eyepiece and/or to the video processing unit. Modern bronchoscopes use the "pure white" light that belongs in the cool range of white emitted by LED lights (usually in the 4800–6000 K (Kelvin) range). The light is being transmitted via glass fibers that run through the entire length of the bronchoscope and end at the distal tip [10].

Image Acquisition: In the fiberoptic bronchoscopes, the image is being transported with a bundle of precision fibers from the distal tip to the eyepiece that is in the head of the handle of the bronchoscope. In the video bronchoscopes, the image is transferred to the video processing unit via a chip called Charged Coupled Device (CCD). The chip was initially placed near the tip of the bronchoscope, while in the newer scopes, it is housed in the head of the scope. The light emitted from the light source illuminates the airway and it is reflected back to the CCD that creates an image by converting it into signals for Red, Green, and Blue (RGB). There are two different technologies currently employed. The first is called "RGB sequential" (also known as "black & white" system) and it records the three signals sequentially using a rotation RGB filter. This technique creates images of great quality and it can be miniaturized thus allowing the development of smaller scopes. Its major disadvantage is that if the scope moves too fast in relation to the rotating filter, it may create distortion of the colors referred to the "rainbow effect." The other technology (RGB color chip) is utilizing sensors called pixels (a different one for each color) that record all three colors simultaneously. The method is fast and thus it significantly reduces the "rainbow effect." Its main disadvantage was its size that prevented its use in small scopes. However, the advances in technology have decreased its size sufficiently and it is now the predominant method for image acquisition in most countries including the USA. Both the color chip and the RGB sequential methods require a video processing unit that receives the signals with wires and converts them into actual image [10].

Movement Control: The bronchoscope is inserted and advanced into the airways manually. The direction is controlled by a horizontal lever that is located on the head of the handle. The lever moves up or down and flexes the tip of the bronchoscope upwards and downwards. The upward angulation in the older flexible bronchoscopes is 180°, whereas in the newer videobronchoscopes, it reaches 210°. The downward angulation is standard at 130° (newer types of disposable bronchoscopes offer increased downward angulation). It should be noted that the lever is moving in the opposite direction of the tip of the bronchoscope (i.e., pushing the lever downwards angulates the tip of the scope upwards and vice-versa). Change of the direction to the left or to the right can be achieved by rotating the shaft of the scope clockwise or counterclockwise. This can be best achieved by creating a "loop" (Fig. 14.5) and holding the shaft gently with the tips of the thumb and the index or middle finger. Attention should be paid that the loop is not tight, so the fibers are not damaged. It is important not to exert pressure and not to attempt to twist the shaft with force. Inexperienced bronchoscopists often twist the shaft as if they are using a screwdriver. This will not only damage the shaft (especially the fibers) but it actually prevents its rotation. As a rule of thumb, if one uses the wrists, especially of the hand that holds the shaft, they are using the bronchoscope the wrong way. On certain occasions such as when using the bigger less flexible bronchoscopes or when the bronchoscope is inserted through an endotracheal tube deep enough, and there is not enough length to create the loop, the shaft can be rotated by rotating the body of the bronchoscope. However, the rotation is limited by the flexion of the wrist of the operator.

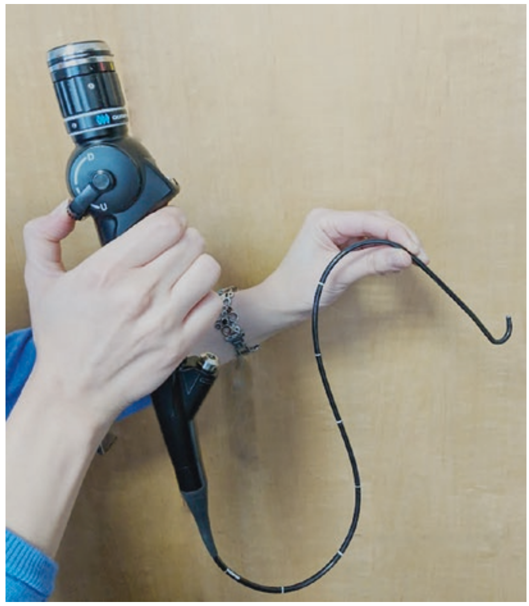


Fig. 14.5 Demonstration of the "loop" of the shaft and of the angulation of the tip

In addition, rotation of the head of the scope also rotates the suction and the working channel valves, thus making them inaccessible to the assistant. To minimize these problems, certain newer bronchoscopes are equipped with a ring located at the bottom of the handle that allows partial rotation of the tip of the scope thus facilitating the insertion into areas with sharp angles (e.g., the right upper lobe). It also allows the rotation of the valve of the working channel toward an assistant without changing the position of the handle.

Whether the body of the bronchoscope should be held with the left or the right hand has been a point of debate. Many argue that the fact that the lighting/video cable and the suction tubing originate from the left side of the body, implies that the body should be held by the left hand so the cable and suction tubing are out of the way. Others insist that holding the body with the right hand and the shaft with the left is superior. We believe that the best handling is whichever makes the bronchoscopist comfortable (determined to a large extent by whether the individual is right-handed or left-handed).

Access

The "preferable" entry point of the bronchoscope into the airways remains rather controversial. There are many different routes and very strong opinions in favor or against each one of them. We believe that there are no inherently "good" or "bad" routes and that the selection should be decided on a case-by-case basis. The preferred route should satisfy three basic criteria: (a) to maximize the reliability of the findings, (b) to maximize the safety of the patient, and (c) to maximize the easiness of the procedure. However, the relative importance of these criteria changes from patient to patient in accordance with the indication(s) of the procedure. For example, although an endotracheal tube provides maximal "safety," it is contraindicated when the indication for the procedure is to evaluate stridor in an infant because it completely obscures the extrathoracic airways that are most likely the part of the airways that produces the symptom. On the other hand, an endotracheal tube is acceptable (or preferable) if the indication for the bronchoscopy is to obtain cultures from bronchoalveolar lavage in a patient with diffuse pneumonia. Table 14.2 summarizes the relative usefulness of each route in relation to the indication(s) for the procedure.

Entering the Airways

If one passes the bronchoscope through the nose in a spontaneously breathing individual, the larynx should be visible as soon as the bronchoscope passes the soft palate. However, the view may be obscured by a variety of factors such as large amount of lymphoid tissue, the shape of the epiglottis (the infant epiglottis is Ω-shaped and in a horizontal rather than in an upright position, often almost touching the posterior pharyngeal wall). Collapse of the epiglottis onto the posterior pharyngeal wall can be seen even in a normal person under anesthesia. If a laryngeal mask airway is used, the epiglottis is compressed and flattened, obstructing (partially or completely) the view of the glottis. In such cases, one has to move the bronchoscope slightly downwards in the midline, flexing slightly upwards as soon as the tip is under the epiglottis (the movement resembles using a gardening shovel to unearth a root) and then flexing downwards as soon as the vocal cords are in good view in order to enter into the subglottic space and the upper trachea. Alternatively, one may attempt to enter from the side of the epiglottis. Hyperextension of the neck and occasionally cricoid pressure may be helpful. The glottis and the subglottic space are very sensitive and even when the area has been anesthetized with lidocaine, the touch by the bronchoscope and/or inadvertent suctioning can easily cause laryngospasm that can cause significant problems in oxygenating and ventilating the patient. Thus, one has to go through these structures as fast as possible. In fact, the subglottic space is much easier to inspect as the bronchoscope is being withdrawn. Laryngospasm often resolves spontaneously. If it persists, application of positive airway pressure

Table 14.2 Criteria for the selection of the route of insertion of the bronchoscope relative to the indication(s) for the procedure

	Abnormal breathing sounds			Structure/dynamics of trachea & bronchi			Procedures (bronchoalveolar lavage; biopsies)		
ROUTE	Easiness	Safety	Reliability	Easiness	Safety	Reliability	Easiness	Safety	Reliability
NASAL	+ +	+ +	+ + + + +	+ +	+ +	+ + + + +	+ +	+ +	+ + + + +
LMA	+ + + + +	+ + + +	+ +	+ + + + +	+ + + +	+ + + + +	+ + + + +	+ + + + +	+ + + + +
ETT[a]	Not indicated			+ + +	+ + + +	+ +	+ + + +	+ + + +	+ + + + +
T-TUBE[a]	Not indicated			+ + +	+ + + +	+ + +	+ + +	+ + + +	+ + + + +
FACE MASK	+ +	+ + +	+ + + +	+ +	+ + +	+ + + +	+ +	+ + +	+ + + + +
ORAL	+	+ +	+ +	+	+ +	+ +	+ +	+ +	+ + + + +

LMA laryngeal mask airway, *ETT* endotracheal tube, *T-tube* tracheostomy tube

[a]Although endotracheal tubes and tracheostomy tubes are the most secure airways and allow for full ventilation, their effectiveness is often limited because the bronchoscope obstructs a significant portion of their lumen

may relieve it. In rare cases, paralysis with succinylcholine may become necessary.

Upon entering the subglottis, the tip has to be flexed slightly downwards so it stays in the center of the tracheal lumen. Generations of pediatric pulmonary fellows have been trained by hearing the phrase “off the wall” uttered calmly (or screamed) by their instructor. Keeping the bronchoscope in the center of the tracheal lumen is not only for safety purposes (in order to avoid “scratching the tracheal or bronchial wall”). It is also the only way to reliably assess the shape of the trachea, to verify the presence of the tracheal rings only on the anterior wall and not on the posterior wall, to detect external compressions, and to assess the degree of collapse due to malacia. In a normal trachea, one should have a tunnel view of the entire trachea, the main carina, and the take-off of the main stem bronchi.

There is no specific guideline as to whether one should inspect first the right or the left lung. However, developing a specific routine helps one to remember to inspect all the segments. It is also useful, in retracing one’s steps during the review of the pictures/videos that were hopefully taken during the procedure. However, if the patient is unstable one should inspect first the area of interest.

There are also no specific guidelines as to whether and how many pictures and/or videos one should take during a bronchoscopy. In the past there were significant practical limitations to picture taking (they were time consuming, they could not be taken by the bronchoscopist but only by an assistant, and they were expensive). The modern bronchoscopes and the digital photography virtually eliminate all these problems. We recommend taking pictures of all lobar and segmental bronchi and, of course, of everything that is or is suspected to be abnormal. Because after the first couple of generations, all airway divisions look very similar, it is very helpful if a record of where exactly each picture was taken is kept. Videos are also very helpful especially for training purposes. While an experienced bronchoscopist can inspect both lungs in less than a minute, a novice bronchoscopist may take much longer to just move the bronchoscope a few millimeters (or not at all). Sometimes, this is because of anxiety that advancing the bronchoscope may cause some damage, or because they are not sure of how to proceed, or because they cannot appreciate the passing of time. In addition, because their concentration is on handling the bronchoscope, they may overlook significant pathology (especially dynamic changes). Reviewing the videos afterwards clearly illustrates the unnecessary delays and allows the instructor to point out areas of interest as well as practical tips.

Although a bronchoscopy is not a race, time is of essence and effort should be made to keep the procedure as short as possible. The duration of a bronchoscopy varies, in part due to the differences in experience and skill among bronchoscopists but also because of the different indications for the procedure. For example, doing a BAL to obtain cultures in a patient with diffuse lung disease can be accomplished very fast because one can lavage the most easily accessible segment. On the other hand, looking for the site of occult bleeding will undoubtedly take much longer time because each and every accessible segment has to be inspected. If and when the concern is about tracheobronchomalacia, it is advisable to wait until the patient coughs so the dynamic collapse can be observed. This means that the anesthesiologist has to let the patient wake-up, something that often may take several minutes.

Other Perioperative Issues

As it was mentioned, a bronchoscopy involves many different elements that a trainee must learn and master. Several of them are being discussed in other chapters of this book. Thus, we briefly discuss only a few.

Consent

The consent for the procedure is both a legal and a medical document. Each hospital has its own forms that have been reviewed by their legal departments and which should be followed as instructed. Despite certain (often stylistic) differences between them, all consent forms cover two major areas. The first is to specify what exactly is to be done to the patient. The second is to explain the possible complications that may develop during and/or after the procedure so the patient (or the parent/guardian) can be fully informed before giving their approval.

FB is generally a safe procedure when all necessary precautions are taken, but the potential of adverse effects cannot be entirely ruled out. Such complications can be categorized as follows: (a) adverse effects that are minor, very common and largely "unavoidable" (e.g., increased cough and/or sore throat due to pharyngeal and/or laryngeal irritation from the use of a laryngeal mask airway (LMA) or of an endotracheal tube or of the bronchoscope itself; (b) complications that are serious but preventable (e.g., aspiration of large amount of gastric contents can be a very serious adverse effect but a very unlikely one if the patient follows the instructions about restricting food and fluid intake several hours prior to the procedure); and (c) complications that are serious and can potentially happen even when precautions are taken(e.g., transfusion of platelets during the procedure minimizes but does not rule out the risk of bleeding in a patient with active coagulopathy). In general, the consent should inform about all the possible adverse effects that are directly related to the procedure but it is prudent to explain that the likelihood of any of them happening is considerably different depending on the circumstances (for example, a pneumothorax is unlikely to happen during a regular airway inspection, but relatively high after a transbronchial biopsy).

The Bronchoscopy Report

Writing a good bronchoscopy report is almost as important as the procedure itself. It should be detailed, factual, and easily understood by those who read it. It serves as the official document that describes what was done to the patient, by whom and how, and most importantly what was found. There is no universally accepted template for a bronchoscopy report. The software programs provided by the manufacturers of bronchoscopy equipment do provide bronchoscopy reports that auto-populate with the labeling of the pictures. Despite the convenience, they tend to be rich in (often redundant) detail but poor in terms of context (as well as in terms of grammar and syntax). Attempts to modify them into a more readable narrative are rather time consuming and cumbersome. An alternative is for every center to develop their own template in their electronic medical record system.

The report should give an as complete as possible description of the findings. With regard to the procedure, it should specify who participated and their role (e.g., primary bronchoscopist, assistant etc.), the equipment used and the exact procedure(s) done. The amount of detail in describing how the procedure was performed varies among bronchoscopists. Some describe step by step the movement of the bronchoscope. Others (including the author), argue that since there are really very few options as to how to advance the bronchoscope (e.g., the only way to move from the right lung to the left lung is by withdrawing the bronchoscope to the level above the carina), there is usually no reason to describe in excruciating detail how each step was performed. Instead, the emphasis should be on creating a cohesive narrative that starts with the indications for the procedure, the detailed description of the findings and an impression as to whether and to what extent the procedure answered any of the questions that made it necessary in the first place. The findings should address at the minimum the following:

For the Larynx

- Is it structurally normal?
- Is there evidence of laryngomalacia (if yes, which cartilages are involved and how severe is the obstruction)?
- Is there evidence of laryngeal cleft? ("normal" appearance does not rule out presence of a type 1 cleft)
- Are both vocal cords visible? Are they mobile? If not, are they in adduction or in abduction?
- Is the mucosa edematous and/or erythematous?
- Are there any mucosal lesions (e.g., nodules, ulcers, and plaques)?

For the Tracheobronchial Tree

- Are the airways patent?
- Is there any visible narrowing (e.g., subglottic stenosis and/or tracheal stenosis)?
- Are the rings visible in the cartilaginous airways?
- Is there a well-delineated membranous portion?
- Is there external compression and where? If yes, is it pulsatile?
- Are there significant dynamic changes in the airway lumen between inspiration and exhalation, during cough or with suctioning?
- Are there anatomical variations (e.g., tracheal bronchus and right upper lobe with only two instead of three segments etc.)?

(a) *Endobronchial findings*:
Are there any nodes; tumors; foreign bodies; mucus plugs?

(b) *Mucosal appearance*:
The appearance of the mucosa should be described in terms of its (a) color (e.g., erythematous and pale), (b) texture (e.g., smooth, eroded, and atrophied), (c) presence of abnormal lesions (e.g., nodules and ulcers), and (d) friability.

(c) *Secretions*: the secretions should be described in terms of (a) quantity (small or moderate amount; copious); (b) location (diffuse, localized); (c) appearance (clear; hazy, milky, frothy; purulent); (d) consistency (thin, thick); (e) color (white, yellow, green, bloody); mucus plugs.

Ideally, each positive finding should be accompanied by a picture.

If the bronchoscopy does not reveal any abnormalities, one could make a general statement such as “the larynx, trachea, and bronchi were anatomically normal. There were no abnormalities in the mucosa. There was only a small amount of clear secretions". The FB is a procedure that provides evidence supporting or ruling out a certain diagnosis, but it does not provide a specific diagnosis by itself. This should be conveyed in the impression.

Part 2. How Should the Bronchoscopy Be Taught?

Although trainees learning FB are already highly trained physicians, it remains a learning process, and as such, it is subject to education theories about learning. Education specialists distinguish three different types (domains) of learning: the “cognitive learning” in which the trainees acquire knowledge that they can then apply into solving problems; the “psychomotor learning” in which the trainees acquire skills with exposure and practice; and the “affective learning” in which the trainees develop the ability to reliably appraise their own knowledge and work toward further advancement. It is obvious that the bronchoscopy by itself is only a relatively narrow manual skill and as such, it falls primarily into the domain of psychomotor learning. However, learning how to incorporate it into one’s practice (why and when to do it) touches the other domains as well.

Generations of bronchoscopists learnt to perform the procedure by observation (i.e., by observing an experienced physician perform it and then attempt to do it by themselves under the guidance of the more senior person. There was very little systematic teaching about all the other elements (indications, consent, perioperative care, etc.) In recent years, several publications have criticized the old “Halsted method” and have promoted more contemporary educational theories, such as Peyton’s four-step approach [6–9]. In this, the instructor demonstrates the procedure; then the instructor repeats the procedure but explains step-by-step how it is done; then the instructor repeats the procedure following the trainee’s step-by-step instructions; finally, the trainee performs the procedure independently. Although the various published studies show benefits of this approach, they are limited to a one-time teaching and not to a continuous process.

One could argue that the teaching of bronchoscopy is very similar to driver’s education.

The latter consists of four parts: (1) a theoretical part that discusses general concepts about cars, describes and discusses the traffic rules, teaches the meaning and significance of traffic signals, and provides a heavy dose of caution for accident prevention; (2) a practical part, during which the student learns the basic processes of driving (how to start the engine, how to hold the steering wheel, how to look at the road, how to make turns, how to park, etc.), but in a controlled environment such as an empty parking lot; (3) the driving, in which the student is actually driving the car under supervision in the traffic; and (4) the evaluation of competence part, in which the student performs certain predefined tasks that if done successfully, convey the license to drive independently. The teaching of bronchoscopy consists of a theoretical part that teaches the anatomy and physiology of the airways, the indications for the procedure and the possible complications. The second part consists of learning how to use the bronchoscope (how to hold it, how to advance it into the airways, how to turn it, and how to "park" it (i.e., wedge it in order to perform a bronchoalveolar lavage). The third part is practice of the first two parts over and over again until the skill is mastered. The fourth step should include the assessment of the trainees' performance that should certify them to perform the procedure independently.

The teaching of bronchoscopy should be a continuum throughout one's fellowship. The theoretical part should be incorporated into the overall teaching of pulmonology. The practical part (i.e., how to use the bronchoscope) has to be taught in the beginning so the trainees can perform it effectively and safely (for the patient and for the bronchoscope). Traditionally, bronchoscopy was learnt by most physicians on patients. This approach (born by necessity) puts severe limitations to the teaching because patients cannot (and should not) undergo repeated (failed) attempts, nor should they be kept under anesthesia for a long time in order to accommodate the teaching part. Fortunately, learning how to hold the bronchoscope, how to angulate the tip and how to rotate it, as well as how to use the suction and the working channel (e.g., threading a biopsy brush or forceps) can be taught without involving a patient.

Navigating the Airways The basic navigation through the airways can be taught (and practiced) on a model of the tracheobronchial tree. The airway models range from totally inexpensive "home-made" ones to multi-thousand-dollar commercial ones usually made by latex. The introduction and popularization of 3-D printing is promising because it could allow the creation of realistic, detailed models based on the appearance of the tracheobronchial tree in a CT scan [11]. One of their negative aspects is that they are usually made by silicone that can be easily torn especially by novice users.

The major advantage of models is that they can be used over and over again, building confidence on the trainee without posing any danger or creating any discomfort to an actual patient. Models can help the trainees improve their coordination, steady their hand and refine the way they angulate and rotate the scope. Models have also a number of disadvantages such as: (a) size: most models have airways whose size is completely out of proportion with the size of the pediatric or infant airways; (b) complexity: many models do not contain divisions beyond the lobar ones; (c) appearance: models cannot present the complex and variable appearance of the pathologic mucosa; (d) lack of dynamic change. This is a very important limitation because the majority of the airway abnormalities in infants and children are due to external compression (e.g., by a vascular ring) and/or due to dynamic changes in the airway lumen (malacia) during the respiratory cycle. These abnormalities are often exaggerated or minimized with changes in the intrathoracic pressure (e.g., bronchomalacia may result in complete collapse of the airway when the patient coughs. Alternatively, the malacia may be underestimated if the patient is mechanically ventilated with high positive end expiratory pressures (PEEP).

Advances in computer technology and graphics have allowed the development of simulation programs that provide more realistic presentation of the airways and possibly varying scenarios of different pathologies [5, 11–17]. Simulation programs originated in the aviation industry but they have found applications in multiple areas from the military to surgery. Its use in bronchoscopy offers the same benefits with a model (i.e., the ability to practice repeatedly without creating any discomfort or increase the risk for a real patient) but in a much more realistic way and most importantly in an interactive manner. However, simulation has a major disadvantage, namely its cost, that for the advanced versions can run into hundreds of thousands of dollars, something that is prohibitive to virtually any academic program. There is also little incentive for manufacturers to produce specific products for pediatric use because the number of pediatric bronchoscopies is markedly lower than the adult ones. Thus, the use of inexpensive models makes much more sense for most programs. The recognition of the pathology can be taught through video libraries that any program can develop by preserving and editing their own files. From a practical standpoint, we believe that the navigation skills can be acquired and perfected with practice on inexpensive (even "homemade" models).

Duration of Training and Assessment of Competence

The basics of the bronchoscopy can be taught in a very short period of time and this can be accomplished either by one-on-one training or by attending the special workshops or courses that are being offed by professional organizations as well as by individual institutions (e.g., the almost 40-year-old Bronchoscopy course at the Cincinnati Children's Hospital as well as couses and workshops offered by various professional organizations). However, learning the basics does not (or should not) automatically qualify somebody to perform the procedure independently. Currently, there are no specific universally accepted criteria for assessing the competence in bronchoscopy. Virtually every adult and pediatric program base their assessment of the competency of the trainees on quantitative criteria, i.e., how many bronchoscopies a trainee performed during their training (the assumption being that if a trainee has performed a certain number of procedures, he/she has mastered the procedure enough to perform it independently. The number of the minimum bronchoscopies varies, but a general consensus is that trainees in adult Pulmonology need to have performed at least 100 bronchoscopies and 50 procedures with EBUS [18]. In a survey of Pediatric Pulmonology Program Directors [19], the consensus was that 50 bronchoscopies (EBUS cannot be used in infants and small children) would be adequate to qualify somebody to practice independently [4, 20–26]. The difference in the criteria between adult and pediatric programs is rather striking, considering that pediatric bronchoscopies are, if anything, even more challenging than the adult ones. The main reason for the difference is the number of procedures performed during one's training, that are in the thousands in adult training programs but only a few hundred for most pediatric programs. Neither the adult nor the pediatric programs have specific qualitative criteria for the performance of trainees. Thus, there is a movement to move away from the numerical criteria and instead evaluate trainees on their actual performance. At this point, there is no specific metric. We believe that the competency of a trainee should be based on specific metrics based on the following three areas:

A. *The actual procedure*. The trainees should be evaluated on their ability to:
   1. Hold and maneuver the bronchoscope
   2. Navigate through the airways and correctly identify each segment
   3. Number of mistakes (e.g., hitting the wall)
   4. Access difficult bronchi
   5. Ability to perform the FB through different ports of access (nasal; LMA, endotracheal tube; tracheostomy tube)
   6. Complications (e.g., significant desaturations or bleeding)

   The assessment of 1–3 can be done easily in a model; the other three will have to be assessed during the performance of an actual bronchoscopy

B. *The practical aspects of the bronchoscopy*
   1. Choosing the right bronchoscope
   2. Setting up the bronchoscopy cart
   3. Collecting and distributing the specimens
   4. Cleaning/reprocessing the used bronchoscope

C. *The medical aspects of the procedure*
   1. Considering and deciding on the indications for flexible bronchoscopy
   2. Consent
   3. Evaluation & preparation of the patient
   4. Anesthesia and Sedation
   5. The bronchoscopy report (including the verbal communication of the findings to the patient/family)

The assessment of the first part could be done on a 5-point Likert scale while the other two could be more qualitative (e.g., below expectation, satisfactory, above average). The assessment could be done routinely (ideally after each procedure the trainee performs or quarterly or semiannually) so appropriate feedback can be given.

Summary

Flexible bronchoscopy is an established diagnostic modality and occasionally therapeutic modality in the care of children with a variety of respiratory disorders. FB involves both manual skills and theoretical components that should be incorporated into the trainees' overall knowledge of pulmonary medicine. The teaching of the procedure is still lacking a specific curriculum as well as standardized methods of assessing the trainees' competency.

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