Step by Step®

Pediatric Bronchoscopy

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Preface

Pediatric flexible fiberoptic bronchoscopy (FFB) is somewhat difficult but commonly indicated respiratory procedure in neonates, infants and older children.While special equipment is required to perform this procedure, reasonably good skill level as well as manual dexterity is also required.

This practical step by step text has been written to familiarize reader with the commonly available instruments, indications and widely recommended techniques of FFB in neonatal and pediatric age group. The equipment and its maintenance, sedation and anesthesia, post-procedural care and complications are described. In addition, techniques of use for airway inspection, bronchoalveolar lavage, transbronchial biopsy, foreign body removal and airway stent placement have also been described in a simple language. A chapter on rigid bronchoscopy has also been included for completion sake.

Practical use of FFB can only be learned by practice on airway models, anesthetized animals (monkey), and careful observation of the procedure performed on the patients by the expert pediatric bronchoscopist.

Once initiated, the technique can be gradually mastered. Training programs and workshops for FFB

are available in Cincinnati (USA) by Dr Robert Wood as well as in India conducted by IAP (Indian Academy of Pediatrics respiratory chapter).

It is hoped that this text will be helpful to those already performing FFB and to those wishing to learn this procedure.

Praveen Khilnani
Mritunjay Pao

Contents

Chapter 1

Introduction: Flexible Fiberoptic Bronchoscopy

• Praveen Khilnani

Flexible fiberoptic bronchoscopy in children and infants is now recognized and accepted as a diagnostic and, to a certain degree, therapeutic modality.[1-6]

In the late 1970s, Robert E. Wood began promoting the direct examination of the tracheobronchial tree with specially constructed, flexible fiberoptic bronchoscopes (FFBs) suitable for use in infants and children.[7,8]

He is clearly responsible for laying foundation for pediatric flexible fiberoptic bronchoscopy (PFFB), and the training program. This greatly facilitated the use of technique and aided diagnosis and management of various disorders of respiratory tract including vocal cord palsy, laryngo-tracheomalacia,laryngeal web, subglottic stenosis, tracheal stenosis, tumors, inflammatory lesions, tuberculosis, foreign bodies and recurrent atelectasis.

In addition to diagnosis of various disorders PFFB has been instrumental in the following areas:

1. Inspection of airways, primarily the trachea, before decannulation of tracheostomy tube or a change of tracheostomy tube to a smaller or larger size as clinically indicated.
2. In cases of severe tracheomalacia, the FFB is used to measure the exact length from the tracheostomy skin stoma to carina. This enables ordering a custom-made tracheostomy tube with specified dimensions (Bivona or Shiley) that could serve as an effective stent.[9]

3. Measurements and photographic recording of tracheal and main-stem bronchi diameter is possible with the ultrathin FFB as levels of positive end expiratory pressure, bilevel positive airway pressure, or continuous positive airway pressure are adjusted.
4. Guiding life-saving or difficult intubations in cervical traumatic injuries,[10] or other conditions with difficult airway, as well as confirming patency or position of the endotracheal tube.
5. Perform bronchoalveolar lavage as well as transbronchial biopsies.
6. Perform the diagnosis and in some cases removal of foreign bodies.
7. Placing tracheal or bronchial stents in patients with tracheobronchomalacia

In this part of the world PFFB is being used both as an outpatient and an inpatient procedure for diagnostic and therapeutic purposes, mostly by pediatric pulmonary specialists, pediatric intensivists and pediatric anesthesiologists (for difficult intubations). Rigid bronchoscopy is mainly performed by pediatric surgeons, thoracic surgeons and pediatric ENT specialists.

This text has been written with a purpose to familiarize reader with the indications and technique of FFB in neonates and pediatric age group. The equipment available for this purpose and its maintenance, sedation and anesthesia, post procedural

care and complications are discussed. Techniques of use for airway inspection, bronchoalveolar lavage, transbronchial biopsy, foreign body removal and airway stent placement have also been described.

It is hoped that this text will be helpful to those already performing FFB or those wishing to learn this procedure.

REFERENCES

1. Nussbaum E. Flexible fiberoptic bronchoscopy and laryngoscopy in infants and children. Laryngoscope 1983;93:1073-75.
2. Nussbaum E: Flexible fiberoptic bronchoscopy and laryngoscopy in children under 2 years of age: Diagnostic and therapeutic applications of a new pediatric flexible fiberoptic bronchoscope. Crit Care Med 1982;10:770-72.
3. Nussbaum E. Usefulness of miniature flexible fiberoptic bronchoscopy in children. Chest 1994;106:1438-42.
4. Nussbaum E: Pediatric fiberoptic bronchoscopy. Clin Pediatr 1995;34:430-35.
5. Fan LL, Sparks LM, Dulinski JP: Applications of an ultrathin flexible bronchoscope for neonatal and pediatric airway problems. Chest 1986;89:673-76.
6. Wood RE: Pitfalls in the use of the flexible bronchoscope in pediatric patients. Chest 1990;97:199-203.
7. Wood RE, Fink RJ: Applications of flexible fiberoptic bronchoscopes in infants and children. Chest 1978;73:737.
8. Wood RE, Sherman JM: Pediatric flexible bronchoscopy. Ann Otol Rhinol Laryngol 1980;89:414-16.
9. Miller RW, Pollack MM, Murphy TM, et al. Effectiveness of continuous positive airway pressure in the treatment of bronchomalacia in infants: A bronchoscopic documentation. Crit Care Med 1986;14:125-27.
10. Rucker RW, Silva WJ, Worcester CC: Fiberoptic bronchoscopic nasotracheal intubation in children. Chest 1979;76:56-58.

Chapter 2

Bronchoscopic Equipment

- Jyotinder Kaur
- Praveen Khilnani

HISTORY OF BRONCHOSCOPY

Bronchoscopy procedures began about 90 years ago. Gustav Killian was the first to use this technique.[1] Chevalier Jackson improved on the rigid bronchoscope and established bronchoscopy as a standard diagnostic tool.[2] Previously bronchoscopy was used mainly for extracting foreign bodies from the trachea or bronchus, and also for extracting small tumors.

In spite of many improvements, the rigid bronchoscope, the early Jackson type, had a low level of illumination and a limited visual field. However, with the progress of thoracic surgery, the need for bronchoscopy increased. This led to an improved bronchoscope and the development of new fields of diagnosis. Professor Yuzuru Ono, of Keio University, who studied under Professor Jackson, established the Japanese Bronchoesophagology Society; as a result tracheoesophagology made rapid progress in Japan. The widespread use of the improved Jackson-type bronchoscope furthered the development of thoracic surgery in Japan and also accelerated the improvement of the bronchoscope. Kozuki and Hone developed the rigid bronchoscope using glass fibers as a light guide.

In 1954, Hopkins and Kapany[3] developed an optically arranged glass fiber bundle, named it the fiberscope, and suggested its use as a flexible instrument for investigating the stomach. Such a device was first used in 1957 when Hirschewitz used a gastroscope to examine a duodenal ulcer.[3]

In 1966, Ikeda developed the first flexible fiberoptic bronchoscope.[4] This new instrument made it possible to see easily the upper segmental bronchi of the left upper lobe and the subsegmental bronchi which were not clearly viewed with the old type of bronchoscope. According to users of this new fiberoptic bronchoscope, the value and usefulness of this instrument as a diagnostic tool increased markedly. With the technical progress of producing glass fiber, the flexible fiberoptic bronchoscope, which has a diameter ranging from 2.2 mm (Fig. 2.1) to 6 mm, was developed and used widely. It is 15 years since the bronchofiberscope was first developed, and it has been greatly improved during the intervening period.

Currently four Japanese companies and one American company have produced bronchoscopes; over 95 percent of these are made in Japan.

The flexible fiberoptic bronchoscope tip can be widely moved through an angle of 150—180°. This fiberscope is capable of an angle of viewing ranging from 55—120° at the tip; in addition, its visual image is strikingly clear in spite of using glass fibers. Therefore, the old bronchoscope, which showed the proximal bronchus only, has been largely superseded; the new instrument alters the conception of bronchoscopy itself. It shows the area from the lobar bronchus to the fourth order subsegmental bronchi; it also helps the collection of specimens by using biopsy forceps or brushes and these specimens can be examined in a variety of ways.

Now the rigid bronchoscope, and the flexible fiberoptic bronchoscope are widely used for investigating various pulmonary diseases. The use of the flexible fiberoptic bronchoscope has spread widely and the procedure using this instrument is now becoming routine for the pulmonologist, anesthesiologist, intensivist, otolaryngologist, and the surgeon .

Table 2.1 shows various sizes of pediatric flexible bronchoscopes that are available.

Table 2.1 **Sizes of pediatric flexible bronchoscopes**

External diameter (mm)	*Working channel*	*ET*Size+*	*Age group*
2.2	Nil	2.5–3.0	Premature and term infants
2.8	Present	3.5-4.0	Term infants–1year
3.2–3.5	Present	4.0–5.5	Term infants – up to 7 years
4.5–4.9	Present	5.5–6.5	7 years and older

1. ET – Endotracheal tube + Minimum endotracheal tube size through which the flexible bronchoscope can pass

Commonly available Brands include Olympus, Storz, and Fujinon

Olympus has developed a new line of bronchoscopes, the BF-60 series, for high-precision bronchoscopic examination and treatment by offering improvement in insertability; more width on the inside; and high image quality. Following is the description of the different types of scopes, each of them coming

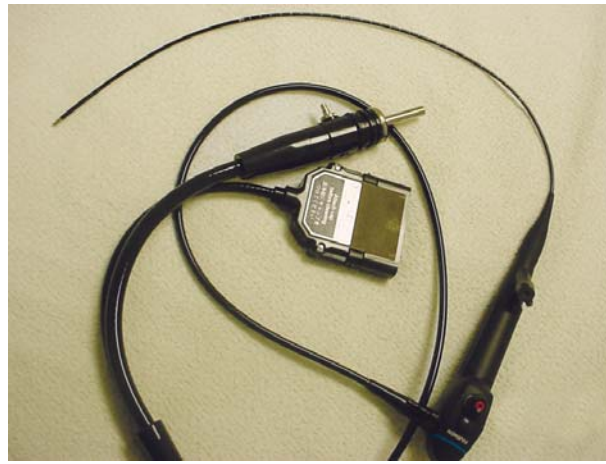

Fig. 2.1: Neonatal bronchoscope

Fig. 2.2: Bronchoscopic videoscope cart

with a unique function.A cart with the videoscope is available to record and print bronchoscopic images (Fig. 2.2).

OLYMPUS BF TYPE P60

The BF P60s image guide has more optical fibers, producing sharper, smoother pictures. It has a wide 120° field of view that brings more of the target site into view. Its 180°up/130°down angulation makes it easier to maneuver the scope in the bronchi and accesses the target site. It is compatible with high frequency electro-surgical devices and with OES and EVIS video system. This scope is ideal for routine applications.

Specifications

Field of view		120°
Direction of view		0° (Forward viewing)
Depth of field		3~50 mm
Distal end outer distance		4.9 mm
Insertion tube outer diameter		5.0 mm
Working length		600 mm
Channel inner diameter		2.2 mm
Minimum visible distance		5 mm from distal end
Bending Section	Angulation range	Up 180°, Down 130°
Total Length		900 mm

OLYMPUS BF TYPE 1T60

This is equipped with an extra wide instrument channel measuring 3.0 mm across that can easily accommodate 2.8 mm diameter forceps and has increased suction power. It has a 120° field of view, 180°up/130°down angulation and a 600 mm working length, which enables accurate observation of a wider area and easy maneuverability in the tracheo-bronchial tree which enhances its therapeutic capability.

Specifications

Field of view		120°
Direction of view		0° (Forward viewing)
Depth of field		3~50 mm
Distal end outer diameter		5.9 mm
Insertion tube outer diameter		6.0 mm
Working length		600 mm
Channel inner diameter		3.0 mm
Minimum visible distance		5 mm from distal end
Bending Section	Angulation range	Up 180°, Down 130°
Total Length		900 mm

OLYMPUS BF TYPE MP60

This scope measures only 4.0 mm across the distal end and 4.4 mm at the insertion tube. This also incorporates a large 2.0 mm wide instrument channel able to

accommodate standard forceps for use in peripheral lung biopsies. This has a wide 120° field of view and 180°up and 130° down angulation for easier for easy maneuvering in the bronchi and is an excellent choice for tracheobronchial applications.

Specifications

Field of view		120°
Direction of view		0° (Forward viewing)
Depth of field		3~50 mm
Distal end outer diameter		4.0 mm
Insertion tube outer diameter		4.4 mm
Working length		600 mm
Channel inner diameter		2.0 mm
Minimum visible distance		3 mm from distal end
Bending Section	Angulation range	Up 180°, Down 130°
Total Length		900 mm

OLYMPUS BF TYPE XP60

This has an extra slim design that measures only 2.8 mm across at both distal end and insertion tube, and a reduced bending radius, which makes it able to reach even the outermost peripheral bronchi. Despite its ultra-thin design, it incorporates an instrument channel measuring 1.2 mm across. Also, it has connectivity to OES and EVIS video systems.

Specifications

Field of view		90°
Direction of view		0° (Forward viewing)
Depth of field		2~50 mm
Distal end outer diameter		2.8 mm
Insertion tube outer diameter		2.8 mm
Working length		600 mm
Channel inner diameter		1.2 mm
Minimum visible distance		1.5 mm from distal end
Bending Section	Angulation range	Up 180°, Down 130°
Total Length		910 mm

OLYMPUS BF TYPE 3C40

This scope delivers excellent optical performance due to the use of extra fine optical fibers. Also, it has a slim design with the distal end measuring only 3.3 mm across. These features allow the scope to penetrate even further into the bronchial tree and see more clearly as well. Its high-resolution images are bigger, sharper and clearer with reduced dot patterns.

Specifications

Field of view	120°
Depth of field	3~50 mm
Distal end outer diameter	3.3 mm

Contd...

Contd...

Insertion tube outer diameter		3.6 mm
Working length		550 mm
Channel inner diameter		1.2 mm
Minimum visible distance		3 mm from distal end
Bending Section	Angulation range	Up 180°, Down 130°
Total Length		840 mm

OLYMPUS BF TYPE N20

This is an ultraslim bronchoscope measuring only 1.8 mm in diameter at the distal tip and 2.2 mm in diameter at the insertion tube. This bronchoscope is best suited for diagnosis of respiratory diseases in neonates and infants. It provides bright, sharp images due to high-resolution image guide fibers and distal end angulation of 160° up and 90° down supports accurate diagnosis.

Specifications

Field of view		75°
Depth of field		2~50 mm
Distal end outer diameter		1.8 mm
Insertion tube outer diameter		2.2 mm
Working length		550 mm
Bending Section	Angulation range	Up 160°, Down 90°
Total Length		840 mm

THE PHYSICS OF FLEXIBLE FIBEROPTIC ENDOSCOPES

A beam of light entering one end of an ordinary glass rod is trapped by repeated internal reflections off the walls until it emerges at the other end. It is this trapping of light within the glass rod that forms the basis for the use of fiberoptics to transmit images.[3]

If a glass rod is heated and stretched, strands less than 25 microns diameter can be formed. These strands become flexible and are more properly termed fibers. The light entering such a fiber is trapped and, after many reflections off the walls (up to 10,000 reflections/meter), emerges uniformly distributed over the exit face of the fiber. A specific or detailed image cannot be transmitted in a recognizable form over a single fiber, since the image is completely blurred on transmission down each fiber. Therefore, the image must be formed as a composite of many such fibers.

A large number of glass fibers fastened together with both ends tightly fixed makes a *Flexible bundle*. However, in order for an optical image to be transmitted through the bundle and subsequently identified, it is essential that the arrangement of fibers at each end of the bundle be precisely the same. This type of organized bundle is called a *Coherent bundle*. In such a bundle, complete optical insulation of each fiber in the bundle is essential. This is accomplished by coating each glass fiber with a 1 micron thick layer of another type of glass,which has a lower reflection index (RI) (a process called

cladding). This helps maintain total internal reflection of light and aids in image transmission along the fiber, even though the fiber may be bent or twisted.

The resolution of an image formed by the composite of individual fibers in a coherent bundle is related to the diameter of the individual fibers. Resolution is improved by increasing the number of fibers in the bundle and using smaller diameter fibers. Glass fibers of 8 or less are not suitable for this purpose, as light is not transmitted well in such a narrow channel.

Light from the subject strikes the distal end of the bundle, is transmitted through the individual fibers in the bundle, and is reconstructed at the proximal end. The proximal image (at the eyepiece) consists of a lattice or raster of small spots of light, each with uniform intensity and color. This is similar to a television picture, which, in like manner, is composed of discrete picture elements or pixels. A typical fiberoptic image bundle has a diameter of 1.5 mm and contains about 10,000 fibers of 10 to 12 microns in diameter. As a consequence, there are only 100 fibers or picture elements at any given diameter of the bundle, giving rise to the graininess seen in magnified endoscopy images. An objective lens is placed at the distal end of the image transmission bundle to focus the object being transmitted by the fibers. An eyepiece, consisting of several lenses, is placed in the handle to focus the proximal image from the bundle onto the viewer's retina and to provide image magnification. Except at the ends where fibers are fused

for strength, the bundle is flexible. However, these fibers are delicate, and breakage may occur. When broken, a fiber will no longer pass its image, and the viewer will view a black dot in that fiber's location.

A fiberoptic bundle is also used to conduct light from an external source to the distal end of an endoscope. This light transmission bundle is subjected to fewer constraints, since no discernible image need be identified. Fiber size can be larger (typically 25 microns), and the fibers do not need to be arranged in a precise manner (*Incoherent bundle*).[3]

The two remaining factors in endoscope design include controls to maneuver the tip and a means for providing a coordinated rotation. Small wires are used to bend the tip via a control lever, and the coordinated rotation is inherent in the basic construction. Coordinated rotation means that the tip rotates to the same degree as the handle when the latter is turned. Thus, the tip can be bent in any direction by a combination of rotation and bending.

BASIC ANATOMY OF A BRONCHOFIBERSCOPE

The basic structure of a bronchofiberscope is shown in Figure 2.3. The major components are:

1. Handle
2. Insertion cord
3. Universal cord

Each of these is designed to contribute to the overall functioning of the endoscope and may come in several

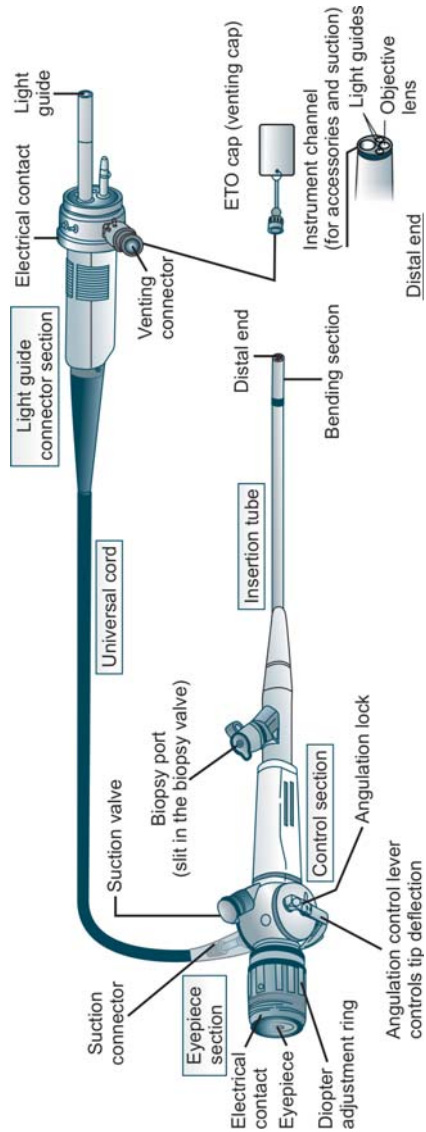

Fig. 2.3: Basic anatomy of bronchoscope

varieties, depending on the particular manufacturer and model. However, several basic generalizations exist across all instruments.[3,4]

The Handle

This part is held by either the right or the left hand and contains the eyepiece for viewing, the lever or knob for controlling the bending motion of the tip, and access to the working (suction or injection) channel.

Most fiberscopes will have a tip locking lever to lock the bending tip at a desired position. This lock is used during bronchoscopic biopsy or photography and is not usually used during airway examination and intubation. Most handles are made to be held comfortably in one hand in such a way that the thumb can maneuver the bending lever and the index finger can regulate the suction. This allows the operator's other hand to be free to manipulate the insertion cord or endotracheal tube. The bending lever, which is located on the back of the handle, controls movement of the insertion cord tip in one plane of motion. Usually, the connection of the handle to the insertion cord is tapered, such that an endotracheal tube may be held there by being pushed onto the taper. The eyepiece contains a diopter adjustment ring to focus and adjust the eyepiece to fit each viewer's eye.

Insertion Cord

That portion of the fiberscope that is inserted into the patient and over which endotracheal tubes are passed

during fiberoptic intubation is called the insertion cord or tube. It contains the light guide and image transmission bundles, the working channel, and the tip bending control wires. These are wrapped with a water-impermeable coating the outside diameter of which determines the size of the smallest endotracheal tube that can be used. The insertion cord is flexible (Fig. 2.4). The only portion of the insertion cord that is designed for maximum bending is the distal tip. This tip is made more flexible by enclosing the contents within a series of metal rings, which are joined by hinges to metal wires along two sides . The tip is then able to bend up and down at right angles to these hinges according to the tension in two control wires. The coating on the tip is made of thin rubber, so that it remains sealed yet flexible. The delicate nature of the rings, wires, bundles, and coating makes this a very easily damaged region.

Inside of a fiberoptic bronchoscope insertion tube. Two angulation wires control the bending of the tip of the fiberscope. Two light guide cables contain fiberoptic bundles (incoherent) which bring light to the tip of the

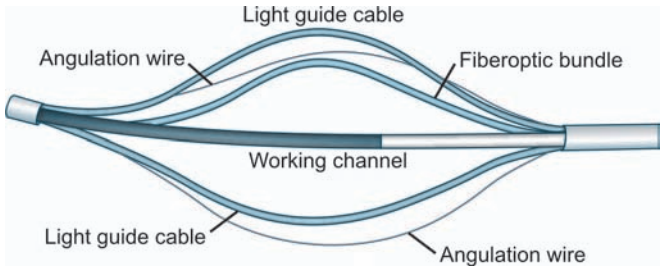

Fig. 2.4: Insertion cord anatomy

fiberscope. The fiberoptic bundle contains the coherent bundle, which transmits images from the objective lens at the tip of the fiberscope to the eyepiece of the fiberscope. The working or suction channel is used for suctioning of secretions and instillation of local anesthetica.

Light Guide Bundles

The light is transmitted through one or two light guide bundles to the tip of the fiberscope. These glass fibers extend to the light guide bundle of the universal cord, which is connected to the external light source.

Image Transmission Bundle

The basic optical construction of the viewing portion of the fiberscope involves the objective lens, image transmission bundle, and eyepiece. Since the distal tip is sealed to eliminate patient secretions and cleaning solutions, focusing by movement of the objective lens is not possible. Thus, the fiberscope is "fixed focus" at the distal tip. Light reflected off the object is focused by the objective lens onto the distal end of the image transmission bundle (object face). This image is then transmitted to the proximal end of the image transmission bundle to the face near the eyepiece (image face). Because the glass fibers in the image transmission bundle are placed so that each fiber is in the same relative location on the image face as the object face, the image seen will faith fully represent that object.

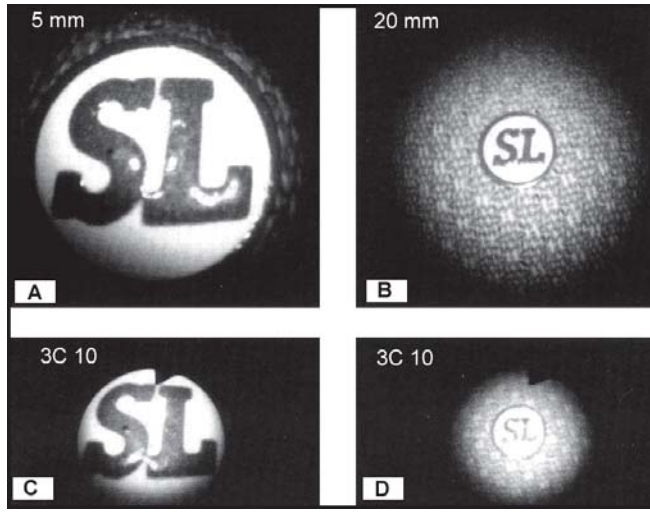

Fig. 2.5: Field of view—A to D: Endoscopic view of letters from 5 and 20 mm distance as seen through two different fiberscopes: (A,B) Olympus 6C10 adult bronchofiberscope and (C,D) Olympus 3C10 pediatric bronchofiberscope

The depth of view field is the range of distances from the tip of the fiberscope within which objects can be located and appear with the same degree of clarity to the viewer. The exact range depends on the fiber size and the effective aperture of the objective lens; however, most fiberscopes have a depth of view field of 3 to 50 mm.

The field of view is the cone-shaped visual field [in degrees (°)] afforded by the design of a particular fiberscope (Fig. 2.5). The field of view of the fiberscope is governed by the number of fibers and the amount of field allocated to each fiber. A wider field of view can be accomplished by increasing the number of fibers

while maintaining detail, or by sacrificing detail with a. smaller number of fibers and allocating more visual field per fiber. Most endoscopes have a field of view of 55 to 100 degrees.

The upper limit of magnification is practically limited by the illumination of the field as well as the design and construction of the small optical system, which must be enclosed at the tip of the fiberscope.

Working Channel

This channel extends from the handle of the fiberscope to the tip of the insertion cord and can be used to suction secretions, inject drugs, insufflate oxygen, or pass various biopsy and brush instruments. For adequate suctioning of secretions, it is recommended that a working channel be at least 2 mm in diameter.

Tip Bending Lever

The bending of the distal section of the insertion tube is achieved by movement of the bending lever located at the handle. Two separate small wires travel from the bending lever to the tip of the fiberscope. When the lever is moved downward, the wire that controls the anterior deflection of the tip is tightened, and the tip of the fiberscope bends upward or anteriorly. When the lever is moved upward, the tip of the fiberscope bends downward or posteriorly. Care should be exercised not to put excessive pressure on the lever when the tip of the fiberscope is against resistance. This will result in breakage of the delicate wire, with

loss of bending control. With substantial usage, and especially with improper handling, loss of distal tip flexion is common.

Distal Tip

All fiberscopes are "frontal view" instruments, i.e. the objective lens is perpendicular to the longitudinal axis of the instrument.

Universal Cord

The universal cord contains the light guide fiber bundle and electrical wiring for the automatic photography exposure system. The universal cord ends at the light guide connector. The light guide connector contains the plug, air vent connector, and electrical contacts and is plugged into the light source prior to use of the fiberscope. The ETO (ethylene oxide) cap must be installed for ETO gas sterilization and aeration, and in the event of transportation. It must be removed prior to immersion of the fiberscope into water or disinfectant solutions, or when the fiberscope is in use.

COMPARISON OF AVAILABLE FIBERSCOPES

Several excellent fiberscopes are currently available. These fiberscopes can be used for a variety of purposes, from upper airway examination and intubation of the trachea to diagnostic and therapeutic bronchoscopy. These fiberscopes can be characterized by several important design criteria that are useful for comparison.

Diameter of Insertion Cord

The diameter of the insertion cord determines the size of the endotracheal tube or airway with which the fiberscope can be used. The inside diameter of the endotracheal tube should generally be 1 mm larger than the diameter of the insertion cord. Thus, a fiberscope of small diameter will be necessary for pediatric applications or for use in a double-lumen tube.

A small fiber-scope, however, has several disadvantages when it is used with larger tubes. These include reduced working channel size, small objective image, excessive flexibility (reducing its effectiveness as a "stylette"), and increased susceptibility to damage. Stiffer insertion cords will partially overcome the greater flexibility of the small fiber-scopes; however, this stiffness obviously reduces the flexibility that is helpful during airway endoscopy and bronchoscopy.

Length of Insertion Cord

The length of the insertion cord defines the usable length of the fiberscope.

The Size of the Working Channel

The presence and size of the working channel should be considered. Secretions and blood obscuring the view is a major cause of failure during fiberoptic intubation. The working channel can be used to suction these secretions during viewing and to assist exposure of the epiglottis and vocal cords. Small channels are inefficient

for suctioning, can easily be clogged with secretions, and must be meticulously cleaned each time they are used. Since the channel increases insertion cord diameter, some small-diameter fiberscopes have eliminated the channel to achieve a smaller overall diameter.

The Field of View

The field of view angle defines the overall picture available to the viewer. A wide field of view will give a good perspective on the anatomy; however, this may sacrifice the resolution or image quality. Fortunately, most of the presently available fiberscopes combine a wide depth of field coupled with a reasonable field of view and image resolution. These qualities, as well as the durability and arrangement of the handle controls, are best evaluated individually.

The Bending Radius of the Distal Tip

The bending characteristics of the distal tip of the insertion cord should be evaluated. Sufficient bending must be available to allow maneuvering in the airway, especially in the presence of pathology or a compromised airway. In general, for intubation of the trachea, the upward flexibility is most important, since the most difficult angle of the airway is usually the upward bend from the posterior pharynx behind the epiglottis into the trachea. However, for evaluation of the bronchial tree and management of the airway in

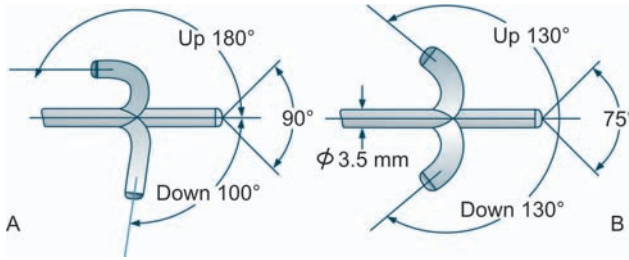

Fig. 2.6: A,B: Bending section of two fiberscopes with different degrees of up and down bending capability and different degrees of depth of field of view

the presence of mass or tumor, both upward and downward bends become critical. Upward bending of 160° or more and downward bending of 120 or more are needed for successful airway management under different circumstances (Fig. 2.6).

The Control Mechanisms of the Bending Tip

The control mechanism of the bending section of the insertion cord is important. The thumb control lever system, which is placed on the back section of the body of the fiberscope, is considered superior by many operators. The maneuverability of the instrument is greatly improved, and the fiberscope can be handled by either the left or right hand without difficulty. Other factors that should also be considered when purchasing a fiberscope are the need for taking pictures, the use of video systems, and the compatibility with existing fiberscopes and light sources. Extremely important are the quality and speed of service provided by the manufacturer. Even with careful handling, fiberscopes

will eventually need repair and servicing. A convenient service provided by the company is the loan of an instrument while repairs are being conducted.

ACCESSORY INSTRUMENTS

A variety of accessories and attachments are available for the fiberscope. Some of these accessories are an integral part of the fiberscope necessary for viewing, cleaning, or testing. Most of the remaining attachments are used either for teaching or for photography.

Light Sources

The ability to distinguish the object depends on adequate illumination; thus, the light source is an integral part of the fiberoptic endoscope system. Various light sources are available, which provide adequate illumination not only for viewing but also for taking pictures or videotapes. An intense light is generated and is focused on the proximal end of the light guide cable by a source lens or a spherical reflecting mirror. A heat filter or reflecting mirror is used to reduce the amount of heat focused on the light guide cable. The powerful light source needed for videotaping is more expensive, but it will provide adequate light for viewing when the fiberscope has sustained damage and part of the light-carrying fibers are broken.

Teaching Attachments

Teaching attachments are available that allow a second viewer to observe as the endoscopist carries out the

procedure. They are attached to the eyepiece of the fiberscope and provide an invaluable teaching aid. The teaching attachment allows splitting of the beam, so that an observer has the same view as the endoscopist.

Forceps and Brushes

A variety of forceps for tissue biopsy and removal of foreign bodies, and different size brushes are available. Anesthesiologists are rarely faced with situations requiring accessories other than the cleaning brush.

CLEANING AND STERILIZATION

After each use, the fiberscope should be cleaned and disinfected to prevent damage to the fiberscope by dried secretions and transmission of disease. Specific recommendations for sterilization or disinfection made by the manufacturer and by each health care facility should be followed. As a general rule, the insertion cord of all fiberscopes is immersible. However, the handle and the universal cord of some instruments may be damaged by immersion in solutions, although most modern fiberscopes are designed to withstand complete immersion in disinfected solutions.

The fiberscope should be washed immediately after use, and the working channel should be flushed with water to remove secretions before they dry. Prior to soaking in disinfecting solution, all portions of the fiberscope to be immersed should be inspected for defects that might allow liquids to enter into the sealed portions. The rubber covering of the distal portion of

the insertion cord should be carefully examined, as frequent use of the fiberscope may cause tears and defects in this covering. Totally immersible fiberscopes should be tested for leaks using a leakage tester and pressurized air prior to immersion in the solution. Since solutions will cause extensive damage to the optical system, the fiberscope should promptly be sent to the manufacturer for appropriate repair when defects are identified.

After inspection, the suction port assembly should be removed, and the immersible portions of the fiberscope should be soaked in disinfectant solution. Solutions recommended vary with individual manufacturers and include 0.5% povidine-iodine; 2% glutaraldehyde; mild, nonabrasive soap solutions; and 0.016% iodophor. Recommended immersion times after use in noninfected patients vary from 10 min for glutaraldehyde, to 20 min for the iodine-containing solutions, to 30 min for the soap solutions. Each solution is potentially caustic to the materials in the fiberscope, and, thus, the manufacturers' recommendations for disinfectant concentration and maximum soaking time should be carefully observed.

The working channel should be filled with disinfectant solution using a syringe. The use of a cleaning brush may be needed for removal of secretions from the working channel. The brush should only be inserted at the handle end to avoid kinking of the brush in the fiberscope and subsequent difficulty removing it. Finally, the fiberscope should be washed and the

working channel suctioned with water to remove all traces of the disinfectant solution. The portions of the fiberscope that cannot be immersed are wiped with a cloth containing 70% alcohol; however, the contact time with the alcohol should be limited, as it can destroy the rubber coating on the fiberscope.

If the patient has tuberculosis or other transmissible illness, the entire fiberscope should be sterilized. Fiberscope sterilization is also important prior to use on patients with immune deficiencies. Complete sterilization of the fiberscope can be accomplished by ethylene oxide gas sterilization.

Manufacturers recommendations should be followed, so that damage does not occur. The ethylene oxide cap must be securely attached to the venting connector on the light guide connector and must remain in place throughout the sterilization and aeration process. This is necessary to avoid pressure buildup inside the fiberscope during gas sterilization. This cap must be removed prior to immersion and clinical examination. It is important to recognize that the gas sterilization procedure is lengthy, and it may take as long as 24 hr before the fiberscope is ready for use.

After cleaning, the fiberscope should be dried thoroughly and stored for subsequent use. The ideal container allows the insertion cord to remain straight. Carrying cases or small sterilization trays, in which the insertion cord is bent, are less desirable for storage, as the bending stresses the insertion cord and will ultimately damage fibers. The storage location must be

clean, dry, well-ventilated, and maintained at room temperature. Direct sunlight, high temperature, high humidity, and X-ray exposure may cause fiberscope damage.

THE FIBEROPTIC CART

The immediate availability of a fiberscope, light source, ancillary equipment and routinely used supplies is critical for effective application of the fiberscope in airway management. A properly equiped fiberoptic cart with large wheels is ideal. The cart should have a minimum of three shelves or drawers. The cart can be moved to the operating room or to the bedside at short notice to allow convenient access to all the accessories used for airway endoscopy and intubation (see Fig. 2.2).

SUGGESTIONS FOR FIBERSCOPE USAGE

A variety of do's and don'ts have been suggested to improve the usage, avoid the complications, and in crease the life expectancy of the flexible fiberscope.[4] The following is an expanded list of do's and don'ts, which, if carefully applied, will avoid unnecessary and untimely instrument damage.

Do's

1. Do clean, prepare, and check all the necessary equipment and supplies before each use to be certain they function satisfactorily.

2. Do adjust the brightness of the light to a comfortable but minimum effective level to avoid thermal mucosal injury as well as to protect the user's eye.
3. Do lubricate the insertion cord with a sterile watersoluble lubricant.
4. Do adjust the tip of insertion cord to the neutral position before insertion into the endotracheal tube and before withdrawal from the tube.
5. Do advance the fiberscope gently and small distances at a time.
6. Do operate the tip bending lever gently.
7. Do clean the fiberscope and the suction channel immediately after each use.
8. Do dry the fiberscope thoroughly, including all lenses and electrical contacts, prior to storing.
9. Do store the fiberscope with the insertion cord as straight as possible.
10. Do use the correct light source adapter to prevent damage to the universal cord fibers.
11. Do follow hospital and manufacturers' recommendations for cleaning and disinfecting.

Don'ts

1. Do not drop the fiberscope, as it may break and be extensively damaged.
2. Do not sharply bend the insertion cord, as this will break the delicate glass fibers.

3. Do not strike the distal end of the insertion cord on a hard surface, as this may crack the objective lens.
4. Do not squeeze, bend, or twist the distal bending section by hand, as this will damage the bending mechanism.
5. Do not leave the fiberscope plugged into the light source with the lamp on when not in use. This will increase the risk of thermal injury and will reduce the life of the light bulb.
6. Do not scratch the electrical contacts with sharp tools. This will cause damage and improper contact.
7. Do not spill liquids on the head of the fiberscope (nonimmersible), light source, or photographic and videotaping systems in order to prevent equipment damage and electrical hazards.
8. Do not use abrasive cleaners on lens surfaces in order to prevent scratches.
9. Do not withdraw the fiberscope with the angle lock lever in the "engaged" position or while the distal tip is bent. This will cause extensive damage to the bending section and bending control wires and may cause trauma to the airway.
10. Do not twist the fiberscope with force when the tip is in a narrow orifice or tube. This will damage the insertion cord and may cause tissue damage.

11. Do not apply force when bending the tip of the fiberscope, in order to prevent rupture of the bending wires and loss of bending of the tip.
12. Do not expose the fiberscope to direct sunlight, dust, high humidity, and high temperature in order to prevent instrument damage.
13. Do not store the fiberscope in the carrying case. It is airtight and may predispose to organism growth and contamination.
14. Do not expose the fiberscope to excessive X-ray radiation. This will result in a yellow discoloration and darkening of the glass fibers.
15. Do not try to introduce the fiberscope with force in any case.
16. Do not immerse a fiberscope with a venting cap on, or gas sterilize a fiberscope without a venting cap on, if the fiberscope has such a cap.
17. Do not exceed 10 hr of immersion for cold sterilization.

REFERENCES

1. Killian G, Direct endoscopy of the upper air-passages and esophagus: Its diagnostic and therapeutic value in the search for and removal of foreign bodies. J. Laryng. 1902;18:461.
2. Jackson, C., Foreign bodies in the trachea,bronchi and esophagus. Laryngoscope, 1905;15:527.
3. Hopkins HH. The physics of the fiberoptic endoscope. In: Berci G (Ed): Endoscopy. New York; Appleton-Century-Crofts, 1976;27-63.
4. Ikeda, M., Flexible fiberoptic bronchoscope. J. Jpn. Bronchoesophagol. Soc.,1968; 19:54.

FURTHER READING

1. Andranik Ovassapian. Fiberoptic airway endoscopy in anesthesia and critical care Raven Press (New York) 1990.
2. Oho K, Amemiya R. Practical fiberoptic bronchoscopy, 2nd ed. Tokyo; Igaku-Shoin, 1984.
3. Olympus product information 2006.
4. Satoshi Kitamura. Color atlas of clinical application of fiberoptic bronchoscopy. Mosby year book (St Louis) 1990.
5. Stradling P. Diagnostic bronchoscopy, 4th ed. Edinburgh; Churchill-Livingstone, 1981.
6. Zavala DC. Flexible fiberoptic bronchoscopy: a training handbook. Iowa City; Iowa University Press, 1978.

Chapter 3

Indications for Pediatric Bronchoscopy

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INDICATIONS

Most common indications of flexible fiberoptic bronchoscopy (FFB) in pediatrics are those related to either upper or lower airway obstruction including stridor, noisy breathing, snoring of uncertain anatomic origin, or atypical wheeze. Stridor is one of the most common indications for bronchoscopy in children.[1] Vocal cord dysfunction can often be diagnosed on clinical grounds or via spirometry, but the visual identification of vocal cord adduction with the patient conscious and viewing the video screen can be helpful, both from diagnostic and therapeutic points of view. Suspected aspiration of gastric contents or feedings due to swallowing dysfunction appears to be reasonably common in the population seen by most pediatric pulmonologists. Flexible bronchoscopy is commonly performed as part of the evaluation to inspect the airway and perform BAL (Bronchoalveolar lavage) to evaluate for lipid-laden macrophages[2] or bacteriological studies.

The decision to perform FFB in children is made depending on the patient's history, physical examination, and the results of previous diagnostic tests. FFB can be performed for diagnostic and therapeutic purposes or in order to obtain secretions and cells from the lungs. FFB is generally contraindicated for the treatment of massive hemoptysis, and in the diagnosis of acute epiglottitis. Indications for diagnostic bronchoscopy vary with the age of the patient. In children a normal bronchoscopic

examination can be of be as important as a specific finding, because it definitively excludes suspected problems such as foreign body aspiration. The diagnostic yield of FFB can be increased by the information obtained with BAL and biopsy of the mucosa.[3]

The evaluation of airways obstruction, which may involve the upper or lower airway or both, is the most common indication for FFB in children. Stridor or noisy breathing (due to obstruction of the upper airways) is the most common indication for FB in infants. Nasal insertion allows the examination of the adenoids, and the larynx and hypopharynx in the most physiological conditions and often when the stridor is audible. This allows study of laryngeal structure and function during inspiration and expiration. Dynamic obstruction caused by laryngotracheomalacia can also be assessed adequately. Table 3.1 shows indications of pediatric FFB.

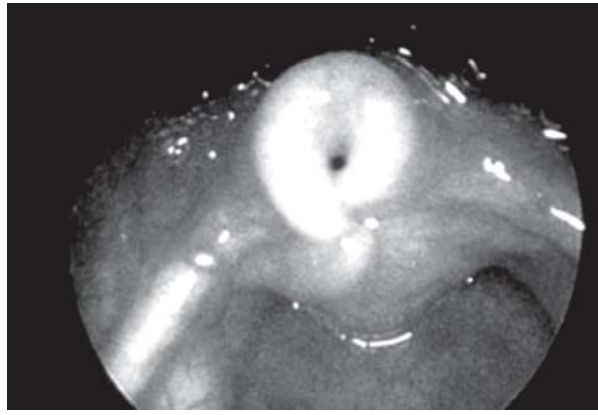


Fig. 3.1: Laryngomalacia

Table 3.1 Indications for pediatric flexible bronchoscopy

Airway obstruction
Stridor/noisy breathing
Persistent/recurrent wheezing

Radiographic abnormalities
Atelectasis
Recurrent/persistent consolidations
Atypical and unknown infiltrates
Localized hyperinflation

Chronic cough
Suspected foreign body aspiration
Hemoptysis
Evaluation of the artificial airway

Therapeutic bronchoscopy
Restoration of airway patency
Mucus plugs or blood clots
Alveolar filling disorders (alveolar proteinosis, lipid pneumonia)

Special procedures
Bronchoalveolar lavage
Brushing or biopsy of the bronchial mucosa
Biopsy of endobronchial lesions
Transbronchial biopsy
Administration of drugs
Endoscopic intubation

The most common congenital laryngeal anomaly and the most frequent cause of persistent stridor in children is Laryngomalacia (Fig. 3.1). Other congenital anomalies of the larynx causing stridor are laryngoceles and saccular cysts (Fig. 3.2), laryngeal webs and atresia, laryngotracheal stenosis, laryngeal and tracheal clefts, congenital neoplasms such as hemangiomas, bifid

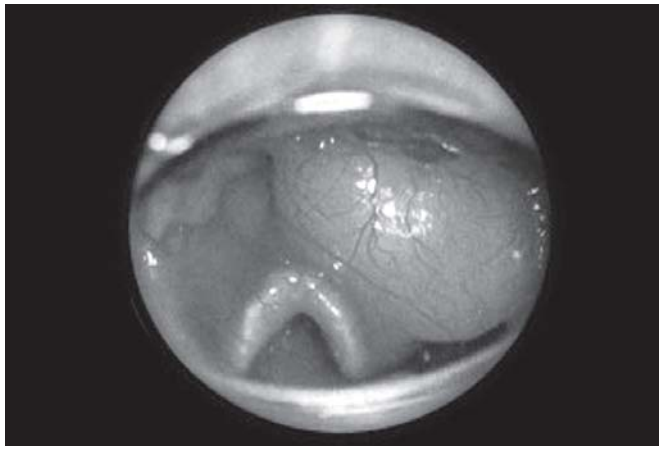


Fig. 3.2: Epiglottic cyst

epiglottis and ventral cleft of the larynx.[4] Laryngeal cleft may be missed by FFB, and rigid bronchoscopy should be performed if this diagnosis is seriously considered. Paralysis of the vocal cords is the third most common congenital laryngeal anomaly producing stridor in infants and children and it is usually the result of congenital anomalies of the central nervous system.

Although there is insufficient data on the frequency of concomitant abnormalities, abnormalities below the epiglottis were found in upto 68 percent of cases.[5] Wood reported that in 15 percent of children examined for stridor and in whom a plausible explanation for the stridor was found at the subglottis or above, there was an additional lesion in the trachea or bronchi. So unless

there is a good reason not to do so, a thorough examination of both the upper and lower airways should be done whenever a bronchoscopy is done.[6] Therefore, if possible, it is important to inspect both the upper and lower airways in any case of airway endoscopy. Although bronchoscopy is not necessarily indicated in every infant with stridor, it should be performed in any child with severe or persistent symptoms, if associated with hoarseness or if it leads to oxygen desaturation or apnea.

Stridor is rare in older children, if not due to recent endotracheal intubation, is always an indication for endoscopy of the airways. Persistent/unexplained wheezing that does not respond to bronchodilator and anti-inflammatory therapy is another clinical indication for FFB, mainly in infants. It is often caused by congenital malformations of the tracheo-bronchial tree such as primary tracheomalacia and bronchomalacia, stenosis and webs of the trachea, tracheomalacia or bronchomalacia secondary to vascular compression (Fig. 3.3), tracheo-esophageal fistula or esophageal atresia, enlargement of the left atrium or congenital cysts.[4]

Localized monophonic wheeze may be present in a child with foreign body aspiration. There are no controlled studies on the indications of flexible endoscopy in the literature, but airway abnormalities were found in 50 percentof cases in one series.[5] It should be noted that FFB is superior to rigid bronchoscopy in

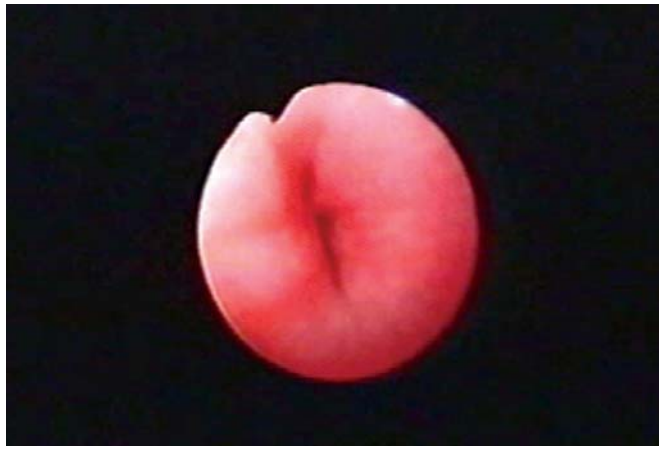


Fig 3.3: Extrinsic bronchial compression

the assessment of airway dynamics, because less positive end expired pressure is applied during the examination.[3]

Complicated, severe, or persistent pneumonias and pneumonias in immunocompromized patients are other common indications for pediatric flexible bronchoscopy. Hemoptysis, undifferentiated lesions in the lung on chest radiograph, and noninfectious parenchymal lung diseases are all less common in children but still lead to elective fiberoptic bronchoscopy at times. When transbronchial biopsy is added to flexible bronchoscopy, the most common indications are those conditions in which histopathology is important in therapeutic decision-making, such as lung transplantation and rare or unusual parenchymal lung diseases. Endobronchial

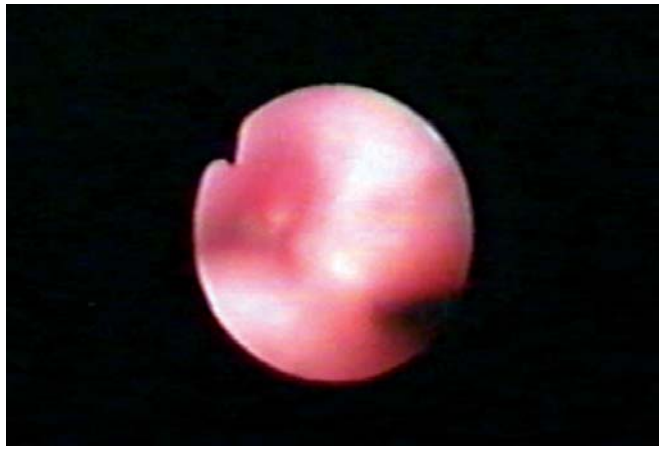


Fig. 3.4: Endobronchial tuberculosis

masses are very rare in children except for foreign bodies and endobronchial tuberculosis (Fig. 3.4). Foreign bodies are virtually always indications for rigid bronchoscopy in most institutions, although a recent data demonstrates excellent safety and efficacy record utilizing FFB with urologic baskets and forceps. A variety of radiographic anomalies represent important indications for FFB in children. Recurrent/persistent atelectasis, recurrent pneumonia, persistent pulmonary infiltrates or mass lesions are radiological indications for bronchoscopy.

Undetected foreign body aspiration, anatomic abnormalities and mucus plugs are commonly found. In these situations, it is also very important to perform BAL in order to obtain pulmonary samples for

microbiological studies and to try to exclude clinical situations such as aspiration and interstitial lung diseases. Localized hyperinflation may be the result of partial bronchial obstruction and can be the consequence of foreign body aspiration, extrinsic bronchial compression and localized bronchomalacia.

Chronic cough both atypical and persistent in a patient with normal imaging, functional studies and hematological examinations, not responding to medical therapy is another indication for flexible endoscopy in children. It helps exclude foreign body aspiration and congenital malformation. A BAL should be performed to try to rule out microaspiration.[7]

Suspected foreign body aspiration can be excluded with FFB, but it is recommended that foreign body extraction in children should be performed with the rigid bronchoscope[8] (Table 3.2). But many bronchoscopists are using FFB to remove foreign bodies with an acceptable success rate. Hemoptysis is a relatively uncommon indication for diagnostic bronchoscopy in children. However, hemoptysis associated with a clear episode of pneumonia should be evaluated with bronchoscopy in order to exclude the presence of a foreign body, malignancy or vascular malformation. Evaluation of an artificial airway (tracheostomy or endotracheal tube) is a common indication for diagnostic bronchoscopy.

Diagnostic flexible endoscopy is also indicated in infants and children with obstructive apnea.

Table 3.2 Flexible v/s rigid bronchoscopy

Flexible bronchoscopy	*Rigid bronchoscopy*
Advantages	**Advantages**
Relatively atraumatic as compared to rigid bronchoscopy	Excellent control of airway
Does not cause mechanical distortion	Use in upper airway obstruction
Inserted with head and neck in neutral position	Therapeutic (removal of foreign bodies and thick mucus plugs, interventional bronchoscopy)
Natural dynamics of the palate and larynx can be visualized	
	Disadvantages
Upper lobes easily visualized	Risk of trauma to the airway
Easy to perform bronchoalveolar lavage	Cannot be passed to the distal airways
Allows bronchoscopic intubations	Difficult to visualize upper lobe bronchi
Can be used in ventilated patients	
Disadvantages	
Partially occludes the airway	
Limited instrumentation (e.g. foreign body removal)	

The diagnostic yield for FFB will depend on the population studied, and the previous investigation and treatment performed.[9] For example, the highest yields for BAL in the immunocompromized host will be before

empirical treatment is started, and in patients not receiving prophylaxis for *Pneumocystic carinii*. There are no internationally agreed guidelines on the expected diagnostic yield for the procedure. Quantitative bacterial cultures of BAL have been used to diagnose pneumonia in immunocompromized and immunocompetent patients. When BAL with <1 percent squamous epithelial cells was analyzed, the finding of >105 colony-forming units of a single bacterial species per ml of BAL was correlated with bacterial pneumonia in comparison with normal subjects.[10-12]

In immunosuppressed patients with diffuse lung infiltrates, *P. carinii* can be identified in BAL with a sensitivity of upto 85 percent.[13-16] Based on response to therapy or histology findings on biopsy or autopsy, the absence of *P. carinii* in BAL in immunosuppressed patients has a negative predictive value of >90 percent.[15-17] In these patients, the sensitivity for detecting *M. tuberculosis* is upto 95 percent. The negative predictive value of absence of *M. tuberculosis* on BAL is >90 percent.[15,16] The role of BAL in monitoring interstitial diseases and chronic infective disorders such as tuberculosis and cystic fibrosis is controversial and undefined for routine use.[18-21] The small size of the working channel is one of the limiting factors for performing a transbronchial lung biopsy (TBB) through the pediatric flexible bronchoscope. The dominant role of TBB is in interstitial lung disease and immunocompromized individuals including lung transplant recipients.[22,23]

Furthermore, in assessing figures of diagnostic yield of an examination, it is important to differentiate diagnoses that are of importance to the child, and findings of mere curiosity value which do not alter management. The indications for therapeutic FFB primarily involve the restoration of airway patency.

Mucus plugs or blood clots in the airways causing atelectasis can be removed with the flexible bronchoscope.[24] Most mucus plugging can be cleared by FFB; just occasionally, rigid bronchoscopy is needed to remove large resistant plugs. Patients with alveolar filling disorders, such as alveolar proteinosis or lipid aspiration may benefit from BAL through a flexible bronchoscope.[25]

FFB can be used in order to perform special procedures such as biopsy of endobronchial lesions, biopsy and brushing of bronchial mucosa, transbronchial biopsy, bronchoscopic intubation and BAL. It is also a tool to administer drugs such as surfactant or deoxyribonuclease (DNase).[26]

Airway problems may be the primary reason for admission to the pediatric intensive care unit (PICU), or arisen as a secondary complication of another illness. Children in PICU may be ventilator dependent, have hemodynamic instability or a coagulopathy. Evaluation of the endotracheal tube position or as an aid to the intubation of the difficult upper airway using a FFB is another reasonably common indication. Flexible bronchoscopes of appropriate size can be passed

through the endotracheal tube or the tracheostomy in order to evaluate the patency or the position of the tube. Children who are not intubated should be managed as indicated above although it may be desirable to transfer them to operating room for the procedure to be undertaken under general anesthesia.[27]

Children who are intubated and ventilated should be under full monitoring. Airway can be maintained using an endotracheal tube, a laryngeal mask or a facemask. In an unstable child, it is wise for the observer to limit the length of time the bronchoscope is down the airway to few seconds.

Hypoxia is common particularly during BAL.[28]

Contraindications

There are no absolute contraindications for flexible bronchoscopy. When the risk of the procedure outweighs the potential benefits, or when respiratory failure in a small infant will not permit the passage of a flexible bronchoscope while gas exchange is maintained , bronchoscopy should be deferred. The decision depends on the skill and experience of the bronchoscopist and clinical practice and the protocol followed by the department/center. Coagulopathy is a relatively strong contraindication to transbronchial biopsy. With use of laryngeal mask, more young patients may safely undergo bronchoscopy with ventilation.

REFERENCES

1. Wood RE. Spelunking in the pediatric airways: Exploration with the flexible bronchoscope. Pediatr Clin NorthAm 1984:31:785-99.
2. Ernst A, Silvestri GA, Johnstone D. American College of Chest Physicians Interventional Pulmonary Procedures: Guidelines from the American College, Interventional Pulmonary Procedures. Chest. 2003;123;1693-1717
3. Midulla, et al. Flexible endoscopy of paediatric airways. Eur Respir J. 2003 Oct;22(4):698-708.
4. Holinger LD. Congenital laryngeal anomalies. In: Holinger LD, Lusk RP, Green CG (Eds): Pediatric Laryngology and Bronchoesophagology. Philadelphia, Lippincott-Raven 1997;137-64.
5. Nussbaum E, Maggi JC. Laryngomalacia in children. Chest 1990;98:942-44.
6. Wood RE. Pitfalls in the use of flexible bronchoscope in pediatric patients. Chest 1990;97:199-203.
7. Fitch PS, Brown V, Schock BC, Taylor R, Ennis M, Shields MD. Chronic cough in children: bronchoalveolar lavage findings. Eur Respir J 2000;16:1109-14.
8. Martinot A, Closset M, Marquette CH, et al. Indications for flexible versus rigid bronchoscopy in children with suspected foreign-body aspiration. A J Respir Crit Care Med 1997;156:1017-19.
9. Chhajed PN, Cooper P. Pediatric flexible bronchoscopy. Indian Pediatrics 2001;38:1382-92.
10. Kahn FW, Jones JM. Diagnosing bacterial respiratory infection by bronchoalveolar lavage. J Infect Dis 1987;155:862-69.
11. Kirkpatrick MB, Bass JBJ. Quantitative bacterial cultures of bronchoalveolar lavage fluids and protected brush catheter specimens from normal subjects. Am Rev Respir Dis 1989;139:546-48.
12. Thorpe JE, Baughman RP, Frame PT, Wesseler TA, Staneck JL. Bronchoalveolar lavage for diagnosing acute bacterial pneumonia. J Infect Dis 1987;155:855-61.

13. Bye MR, Bernstein L, Shah K, Ellawie M, Rubinstein A. Diagnostic bronchoalveolar lavage in children with AIDS. Pediatr Pulmonol 1987;3:425-28.
14. Frankel LR, Smith DW, Lewiston NJ. Bronchoalveolar lavage for the diagnosis of penumonia in the immunocompromized child. Pediatrics 1988;81:785-88.
15. Martin WJ, Smith TF, Brutinel W, M Cockwill FR, Dauglos WW. Role of bronchoalveolar lavage in the assessment of opportunistic pulmonary infections: Utility and complications. Mayo Clin Proc 1987;62:549-57.
16. Stover DF, Zaman MB, Hajdu SI, Lange M, Gold J, Armstrong D. Bronchoalveolar lavage in the diagnosis of diffuse pulmonary infiltrates in the immunosuppressed host. Ann Interm Med 1984;101: 1-7.
17. Williams D, Yungbluth M, Adams G, Glass-roth J. The role of fibreoptic bronchoscopy in the evaluation of immunocompromised host with diffuse pulmonary infiltrates. Am Rev Res Dis 1985;131:880-85.
18. Godfrey S, Avital A, Maayan C, Rotschild M, Springer C. Yield from flexible bronchoscopy in children. Pediatr Pulmonol 1997;23:261-66.
19. Pattishall EN, Noyes, BE, Orienstein DM. Use of bronchoalveolar lavage in immuno-compromized children with pneumonia. Pediatr Pulmonol 1988;5:1-5.
20. Barlogh K, McCubbin M, Weinberger M, Smits W, Ahrens R, Fick R. The relationship between infection and inflammation in the early stages of lung disease from cystic fibrosis. Pediatr Pulmonol 1995;20:63-70.
21. Armstrong DS, Grimwood K, Carlin JB, Carzino R, Olinsky A, Phelan PD. Broncho-alveolar lavage in infants with cystic fibrosis. Pediatr Pulmonol 1996;21:267-75.
22. Marquette CH, Martinot A, Brichet A. Inter-ventional bronchoscopy. Pediatr Pulmonol, 1999; 19(Suppl): 125-29.
23. Wood RE, Prakash UBS. Pediatric flexible bronchoscopoy. In: Prakash UBS (Ed): Bronchoscopy, 1st edn. New York, Raven Press, 1994; pp 345-46.

24. Wood RE. Flexible bronchoscopy in children. In Hilman B (Ed): Pediatric Respiratory Disease: Diagnosis and Treatment. Philadelphia, W.B. Saunders Co., 1993; 111-22.
25. Mahut B, de Blic J, Le Bourgeois M, Beringer A, Chevalier JY, Scheinmann P. Partial and massive lung lavage in an infant with severe pulmonary alveolar proteinosis. Pediatr Pulmonol 1992;13:50-53.
26. Slattery DM, Waltz DA, Denham B, Mahony M, Greally P. Bronchoscopically administred recumbinant human DNase for lobar atelectasis in cystic fibrosis. Pediatr Pulmonol 2001; 31: 383-88.
27. Fan L, Sparks L, Fix E. Flexible fiberoptic endoscopy for airway problems in the pediatric intensive care unit. Chest 1988;93:556-60.
28. Schellhase DE, Fawcett DD, Schutze GE, Lensing SY, Tryka AF. Clinical utility of flexible bronchoscopy and bronchoalveolar lavage in young children with recurrent wheezing. J Pediatrics 1998; 132: 312-18.

Chapter 4

Sedation, Analgesia and Monitoring during Bronchoscopy

• Praveen Khilnani

As a basic requirement, all resuscitative equipment including oxygen, mask, ambu bag, laryngoscope, endotracheal tubes, suction equipment, suction catheters and drugs including atropine, salbutamol and adrenaline must be available.

In addition pulse oximeter and cardiac monitor should be available. At least one skilled assistant to monitor sedation level, vital signs and oxygen saturations is mandatory. Desaturation and bradycardic episodes should be monitored and promptly treated by first removing the bronchoscope out of the airway and giving oxygen until the patient recovers from such an episode. Each pass into the airway tree should not be more than 15-20 seconds specially in hypoxemic ventilated patients in the PICU.

Six hours with nothing by mouth is required for all infants and children before bronchoscopy. An intravenous catheter is secured, and consent is obtained from each patient/parent. The consent form delineates potential risks and complications balanced against targeted objectives and benefits.

Local Anesthesia

This is recommended in addition in patients receiving intravenous sedation to prevent airway reflexes causing minimal cough, bronchospasm or bradycardia.

The nasopharynx, usually the right side, is topically anesthetized by applying 0.3-2.5 ml of 2 percent lidocaine solution, not exceeding 8 mg/kg (to avoid risk

of seizures), followed by local lubrication with lidocaine jelly.[1]

With the exception of tracheostomy evaluation or endotracheal introduction in ventilated children, procedure is performed transnasally. It is important to keep in mind that as the vocal cords are approached, local anesthetic solution is sprayed to anesthetize the vocal cords. This usually results in smooth passage of the bronchoscope without causing the reflex bronchospasm. Laryngospasm may occur but is usually self-resolving. Oxygen may be given throughout the procedure by blowing in front of the face or by keeping the nasal cannulae to prevent hypoxemia. Transtracheal or cricothyroid instillation of local anesthetic solution is usually reserved for older children or adults, to anesthetize the distal tracheal mucosa.

SEDATION AND GENERAL ANESTHESIA

Presedation Assessment

Adequate presedation assessment regarding history of fever or upper respiratory infection, asthma, allergies, significant past history, nil by mouth status, airway assessment and general physical condition is important and should be documented.

Sedation

Intravenous sedation allows the patient to remain reasonably comfortable while ventilation and oxygenation remain adequate. 0.1 mg/ kg intravenous

midazolam to a maximum of 2.5 mg per dose, may be given slowly over 2 minutes. Ketamine, 1-2 mg/kg, or propofol are used if the above modalities fail to achieve appropriate sedation for the procedure . All procedures requiring intravenous sedation are performed in the pediatric intensive care unit (PICU) or the operation theater. When general anesthesia is provided, the flexible fiberoptic bronchoscope is introduced via a customized adapter through an appropriate endotracheal tube or a laryngeal mask airway (LMA). In some centers medications commonly used for sedation are fentanyl 1-3 mcg/kg/h and midazolam 0.1 mg/kg.[2,3] Reversal agents (naloxone and flumazenil) may be used in the postoperative period.

One of the protocols for flexible fiberoptic bronchoscopy (FFB) in the PICU includes one of the following:[4] (1) propofol, 2.5 mg/kg loading dose, and subsequent boluses of 0.5 to 1 mg/kg; (2) ketamine, 1 to 2 mg/kg loading dose, following atropine, 0.02 mg/kg, and midazolam, 0.1 to 0.2 mg/kg; or (3) supplementation of morphine and midazolam boluses in patients receiving mechanical ventilation who were already receiving continuous infusions of these drugs.

With close monitoring of heart rate,respiratory rate and pulse oximetry, most intravenous sedatives can be safely given for FFB in neonates and children. Post procedural monitoring for stridor, bronchospasm, distress or desaturation as well as nausea and vomiting is important. Use of oxygen, nebulization and intravenous steroids may be required if necessary.

REFERENCES

1. Gjonaj ST, Lowenthal DB, Dozor AJ. Nebulized lidocaine administered to infants an children undergoing flexible bronchoscopy. Chest 1997;112:1665-69.
2. Nussbaum E. Pediatric flexible bronchoscopy. Clin Pediatr 1995;34:430-35.
3. Rovner MS, Stillwell PC. Pediatric flexible bronchosopy for the adult bronchoscopist. In: Wang KP, Mehta AC (Eds): Flexible Bronchoscopy. New York, Blackwell Science, 1995; pp 339-62.
4. Zohar DB, Sivan Y. The yield of flexible fiberoptic bronchoscopy in pediatric intensive care patients. Chest 2004;126:1353-59.

Chapter 5

Anatomy for the Bronchoscopist

• Praveen Khilnani

Once the bronchoscope is introduced with the patient in the supine position, and the bronchoscopist at the head end of the patient, the palate will appear at the top, and the posterior pharyngeal wall and the adenoids at the bottom. Beyond the edge of the soft palate, the larynx, esophagus, and the base of the tongue are visualized. Dynamics of movements of the larynx are assessed by placing the bronchoscope just above the larynx and movements are evaluated as the child is made to wake up from general anesthesia. When performed under local anesthesia, these are usually observed before traversing the vocal cords. There are considerable differences between the infant and the adult larynx. The infant larynx is placed more anteriorly in the neck compared to the adult, and it often appears to stand up on a pedestal from the floor of the pharynx. The epiglottis has a much more pronounced curvature (omega or U shaped) compared to the adult epiglottis and the arytenoid cartilages may be very prominent in the infant (Fig. 5.1).

In contrast to the adult, the cuneiform and corniculate cartilages may not be discernible as separate structures in the child. The subglottic space is the narrow portion of the airway in infants and young children as compared to the glottis in the adults. Hence, the selection of bronchoscope for infants and young children should take into consideration that the area beneath the vocal cords is the area of limitation,

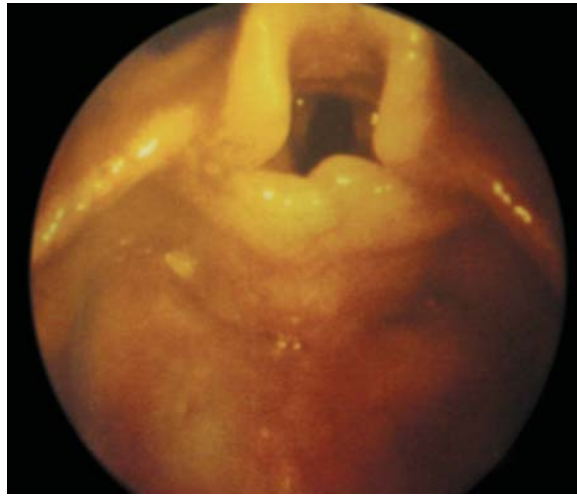


Fig 5.1: Bronchoscopic view of larynx

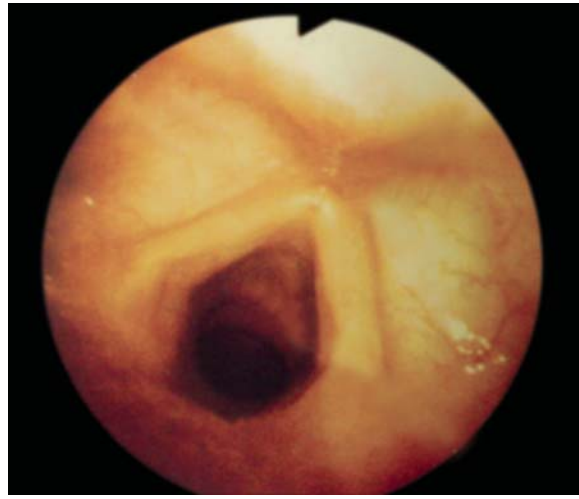


Fig. 5.2: Bronchoscopic view of vocal cords

not the space between the vocal cords as in adults (Fig. 5.2).[1]

The trachea is entered after passing the cricoid cartilage. In children the trachea is nearly round, with the cartilages extending visibly through an arc of approximately 320 degrees (Fig. 5.3). It is normal to see some inward protrusion of the membranous portion of the airways (trachea and main bronchi) on coughing. The main carina is keel shaped and oriented in an anteroposterior plain. In the adult the main carina is sharp and a widened carina in adults may indicate subcarinal lymphadenopathy. In the child the main carina is often quite blunted. The right mainstem bronchus is immediately seen on peering down the

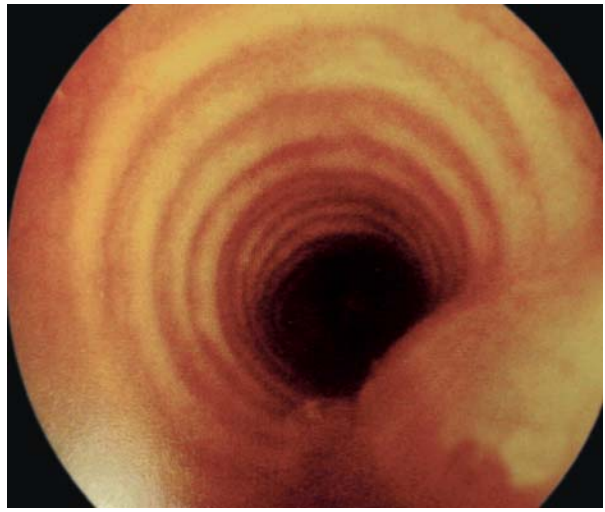


Fig 5.3: Tracheal rings

trachea. The left main bronchus can be visualized in its entirety from the carina, after turning towards the left, and even then it takes a curving course so that its bifurcation cannot be seen from the carina. The shape of the mainstem bronchi is very similar to that of the trachea, with a prominent posterior membranous portion.Various parts of tracheobronchial tree are shown in plates.

The right upper lobe division takes off just beyond the carina at an angle of approximately 100 degrees (Fig. 5.4). The right upper lobe bronchus itself may have a length of 1 cm before dividing into the anterior, posterior and apical segmental bronchi. Beyond the

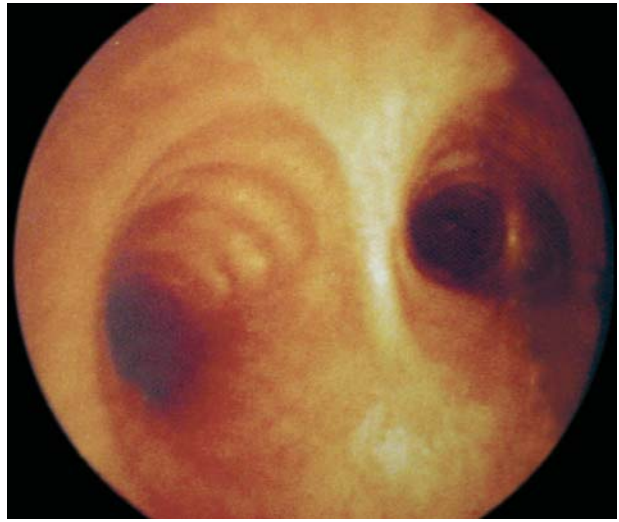


Fig. 5.4: Right mainstem bronchus with right upper lobe bronchus take off

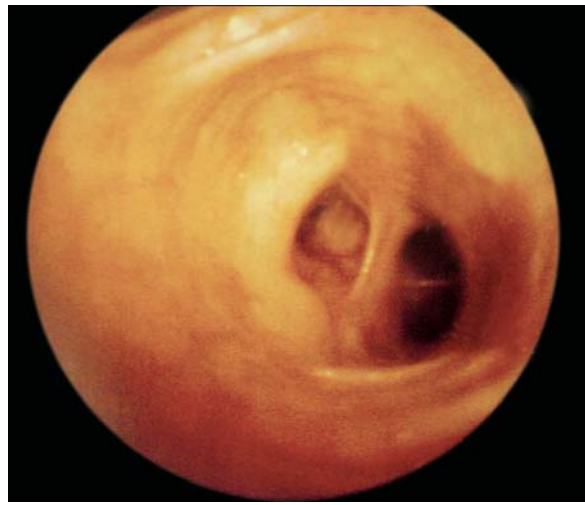


Fig. 5.5: Left bronchus

origin of the right upper lobe bronchus, the right mainstem bronchus continues as the bronchus intermedius. This bronchus may extend for 2-2.5 cm at which point it gives rise to the middle lobe bronchus anteriorly, the superior segment of the right lower lobe posteriorly and the right lower lobe bronchus that divides into basilar segments.

The left mainstem bronchus is 4-4.5 cm in length and terminates into the upper lobe and lower lobe bronchi. As the left upper lobe bronchus ascends superiorly, the lingular bronchus arises and extends slightly downward in an inferior-lateral direction (Fig. 5.5).

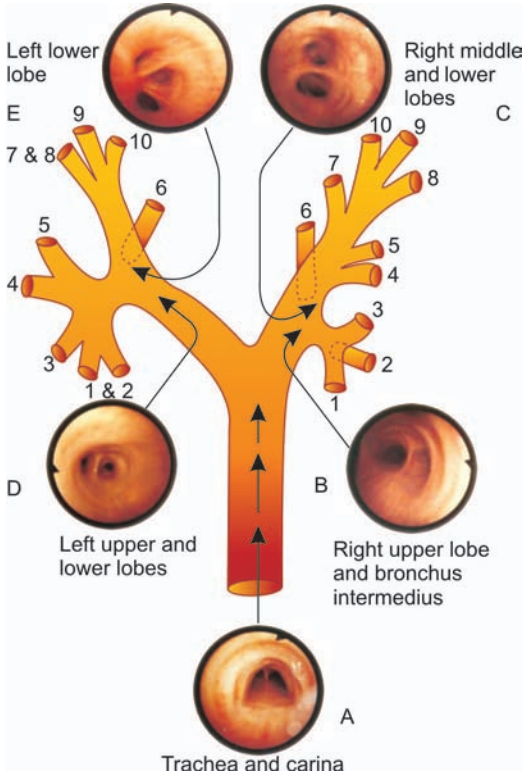


Fig. 5.6: Bronchial anatomy

The upper division bronchus of the upper lobe passes beyond the orifice of the lingula and gives rise to the apicoposterior and the anterior segments. Immediately on entering the left lower lobe bronchus arises the superior segment of the left lower lobe and that descends posteriorly. The left lower lobe bronchus

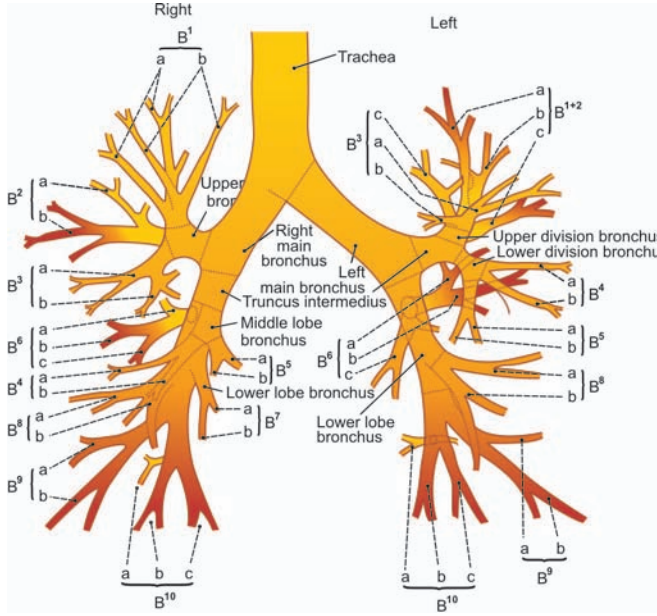


Fig. 5.7: Bronchial tree

beyond the origin of the superior segment is usually 1 cm in length before giving rise to the basal bronchi. Figures 5.6 to 5.9 show the various branches of the bronchial tree using the standard nomenclature.

Bronchoscopic report should use standard terminology regarding the anatomical segments and lesions if any should be clearly drawn and demarkated,with hard copies of still photographs or a video recording

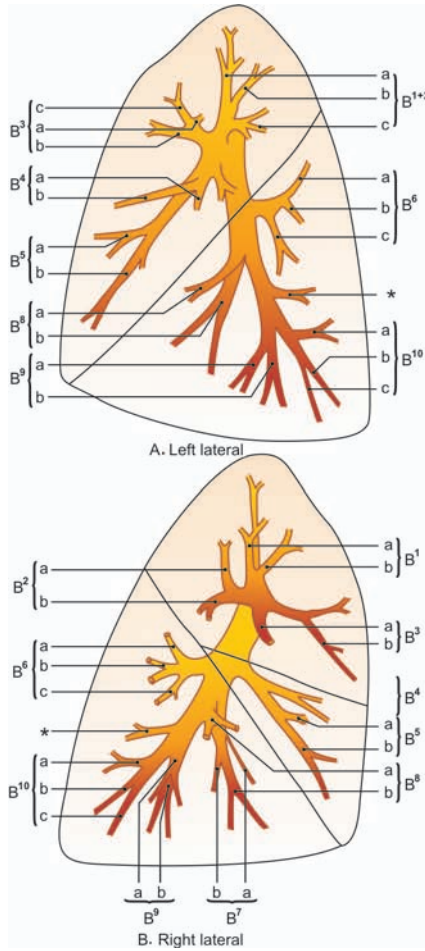


Fig. 5.8: Nomenclature of segments (Japan,1950)

Bronchial nomenclature

	Right lung		*Left lung*	
Upper lobe	B1: R. apicalis	a. Rm. apicalis proprius	Upper division bronchus	a. Rm. apicalis
		b. Rm. (subapicalis) ventralis	B1+2: R. apico-dorsails	b. Rm. (subapicalis)
	B2: R. (Lobi superioris) dorsalis	a. Rm. (subapicalis) dorsalis		c. Rm. (lobisup.) horizontalis
		b. Rm. (lobi sup.) horizontalis		a. Rm. (lobi sup. ventr.) lateralis
	B3: R. (lobi superioris) ventralis	a. Rm. (lobi sup. ventr.) lateralis	B3: R. (lobi superioris) ventralis	b. Rm. (lobi sup. ventr. (medialis)
		b. Rm. (lobi sup. ventr.) medialis	Upper lobe	
	B4: R. medius lateralis	a. Rm. medialis		c. Rm. (lobi sup. ventr.) superior
		b. Rm. medialis		

Contd...

Contd...

Middle lobe					
		a. Rm. lateralis		B4: R. lingualis	a. Rm. lateralis ventralis
	B5: R. medius medialis	b. Rm. medialis	lower superior division bronchus		b. Rm. (lobi sup.) ventralis
		a. Rm. superior	B5: R. lingualis inferior		a. Rm. superior
	B6: R. (lobi inferioris) superior	b. Rm. lateralis			b. Rm. inferior
		c. Rm. medialis	B6: R. (lobi inferioris) superior		a. Rm. superior b. Rm. lateralis
	B7: (lobi inferioris) subsuperior		B7: R. (lobi inferioris) subsuperior		
Lower lobe	B7: mediobasalis	a. Rm. dorsalis			
		b. Rm. ventralis	Lower lobe superior		
	B8: R. ventrobasalis	a. Rm. lateralis			
		b. Rm. basalis	B8: R. ventrobasalis		a. Rm. lateralis
	B9: laterobasalis	a. Rm. lateralis			b. Rm. basalis
		b. Rm. basalis	B9: R. laterobasalis		a. Rm. lateralis
		a. Rm. dorsalis			b. Rm. basalis
	B10: R. dorsobasalis	b. Rm. lateralis			a. Rm. dorsalis
		c. Rm. medialis	B10: R. dorsalis		b. Rm. lateralis

Reference: 1. Jackson LC, Huber JF. correlated applied anatomy of the bronchial tree and lungs with a system of nomenclature. Dis. Chest, 9: 319;1943.

Fig. 5.9: Bronchial nomenclature (Chest, 1943)

REFERENCE

1. Rovner MS, Stillwell PC. Pediatric flexible bronchosopy for the adult bronchoscopist. In: Wang KP, Mehta AC (Eds): Flexible Bronchoscopy. New York, Blackwell Science, 1995; pp 339-62.

Chapter 6

Procedural Technique of Flexible Bronchoscopy in Infants and Children

- Praveen Khilnani
- Mritunjay Pao

PREPARATION OF THE PATIENT

The preparation of the procedure starts with preparing the patient mentally for the procedure and explaining the procedure in detail to the child and parents and taking an informed consent for the procedure. This minimizes the amount of sedation that would otherwise be required in an uncooperative child. The patient must be adequately prepared for the procedure. In the pediatric intensive care unit (PICU), the patient who is being mechanically ventilated, informed consent must be obtained from the parents after explaining the risks and benefits of the procedure.

Oxygen supplementation during the procedure is mandatory in young infants and children especially those with poor respiratory status. Supplemental oxygen can be delivered with a naso-pharyngeal prong through one nostril with the bronchoscope passed down the other or by a facemask over the nose and mouth.

Before the procedure the nose and pharynx must be suctioned after the patient has been sedated and the upper airway anesthetized. A nasogastric tube should be gently passed into the stomach and any contents should be emptied. The patient should be placed supine on the procedure table and gently restrained by an assistant. In younger children, it is helpful to swaddle the arms in a sheet, leaving the chest free for observation and auscultation. ECG electrodes are then attached to monitor heart rate and rhythm. A pulse oximeter to

monitor the oxygen saturation should be used. The assistant should gently hold the head and the shoulders, while reassuring the child gently.

POSITION: FOR NASAL INSERTION

If a nasal insertion is planned bronchoscopy can be performed with the patient lying supine, semirecumbent, sitting facing the bronchoscope or in a lateral decubitus position with the bronchoscopist standing at the head end of the patient. The lateral decubitus position can make the procedure difficult at times. In older patients and adults, some bronchoscopists prefer to perform the procedure with the patient sitting erect and standing facing the patient. But this position is not preferred by bronchoscopists in younger children. Performing the procedure in ventilated patients makes it difficult to stand at the head end. This can be achieved in smaller children by rotating them 90° so the head is at the edge of the bed. A totally supine position is the most comfortable for most patients.[1]

For Oral Insertion

The bronchoscopist can be in front of the patient if he is sitting or stand at the head end of the patient if he is supine. Any change of position of the bronchoscopist also changes the spatial orientation of the tracheobronchial anatomy.

Location

Although the procedure can be performed anywhere in the hospital, it is preferable to perform routine procedure in the central facility or the bronchoscopy room where there are adequate facilities for monitoring and resuscitation of the patient. Assistants should be adequately trained and experienced. Two assistants are usually required the technician and a trained nurse. Anything, which might be needed, will be readily available and this increases the safety of the patients. In sicker children, specially with respiratory distress or oxygen requirement, bronchoscopy should be performed in the pediatric intensive care unit.

Following is the technique currently practiced and recommended by the authors. This technique has been originally described by Dr Robert Wood in his training course.

INSERTION OF THE BRONCHOSCOPE

Transnasal Insertion (Figs 6.1 and 6.2)

Transnasal insertion is the most common, convenient and informative method. It allows complete examination of the upper and the lower airways. After anesthetizing and suctioning the nose, insert the tip of the bronchoscope into the larger of the two nostrils. Before inserting position the tip of the bronchoscope just outside the nostril with the hand braced against the patient's cheeks with the last two fingers of the left hand and then look through the bronchoscope before

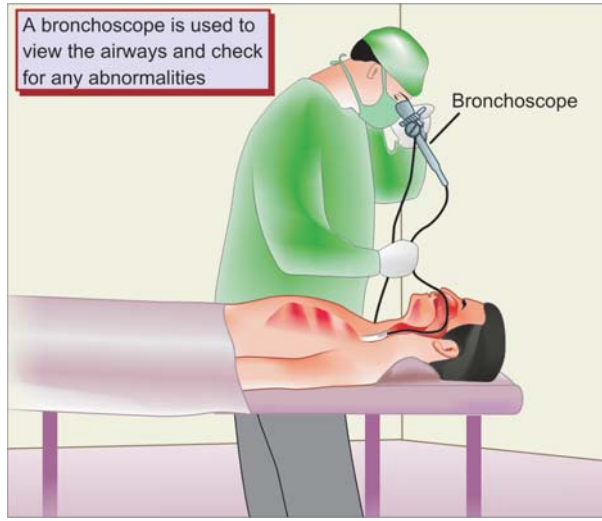
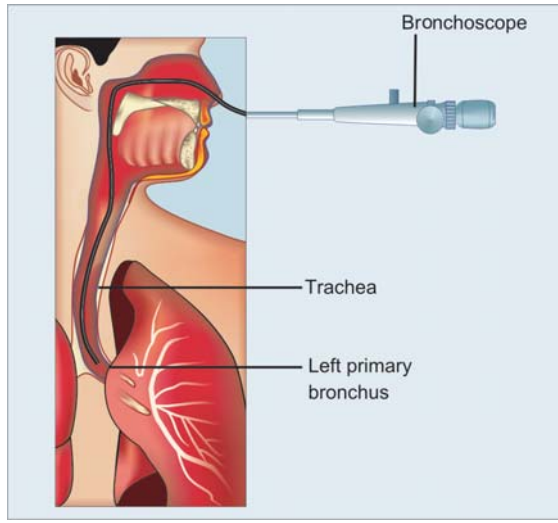


Fig. 6.1



Figs 6.1 and 6.2: Procedure of bronchoscopy: Transnasal insertion

advancing the instrument into the nose. Advance the bronchoscope slowly along the floor of the nose, guiding it under direct vision through the largest passageway you can find. In children this will be the middle meatus, between the inferior and middle turbinates. If you see a triangular passageway, you will most likely be taking the path of least resistance. If you feel resistance, use visual guidance to direct the tip of the scope to advance ahead. Do not aim the bronchoscope up towards the glabella; if you see light illuminating the nose you are going in the wrong direction. Pass the bronchoscope through the nose the same way as you would pass a nasogastric tube. When it is through the nose, look and locate the larynx; examine the nasopharynx on the way back out. Sometimes it is impossible to pass the bronchoscope through the nose on one side, but it will often go easily through the other nostril.

The insertion cord of the bronchoscope should protrude from the nose in such a direction that it does not push or pull on the nares. There is a tendency for all bronchoscopists to pull the tip of the nose upwards with the insertion cord of the scope; this makes the patient very uncomfortable. Hold the scope so that the insertion cord extends out from the nose and then passes slightly down towards the mouth.

The nasal passage is often tight in patients of all ages. Virtually all patients feel some sensation, regardless of the amount or type of local anesthesia. If the patient has been properly prepared to feel pressure rather than

pain, he will most probably remain comfortable. The advancing tip is usually directed caudad. On reaching the nasopharynx the tip should be deflected further caudally and advanced until the base of the tongue and epiglottis is identified. Once the tip of the bronchoscope enters the posterior pharynx, most patients no longer feel much sensation at all. Occasionally, however, it is helpful to put more topical anesthetic in the nose. As you get closer to the choanus spray another small amount of topical anesthetic on the posterior wall. It is against this wall that the insertion cord of the bronchoscope will push as it is advanced it into the lung. Effective anesthesia along the posterior pharyngeal wall will help ensure a smooth, comfortable passage. To achieve good control keep the insertion cord of the scope as straight as possible. The major advantage of this route is that one can avoid the tongue and the teeth.

Oral Insertion

Direct transoral insertion is rarely used. The tongue being one of the strongest muscles of the body pushes the bronchoscope as attempt to enter the larynx through the mouth is made. In a sedated patient the assistant can hold the tip of the tongue and pull it outwards to one side. The gag reflex is very difficult to suppress, and the oral route is much less comfortable for most patients. The angle of the larynx is more difficult than in a nasal approach. A bite block should be used whenever oral route is used, because a bite on the bronchoscope can easily damage it.

Fig 6.3: Holding the bronchoscope

The bronchoscope should be held straight without any curve (Fig. 6.3). Maintain a route along the midline to identify landmarks such as the uvula, the back of the tongue and the epiglottis. Avoid contact with the mucosa and the glottic apparatus as far as possible to minimize gagging and deglutition reflexes so that the anatomy and function of the vocal cords and surrounding areas can be examined properly.

Insertion through Endotracheal Tube

In patients with a preexisting endotracheal tube (already intubated), this route is used if the tube is big enough. The 3.5 mm bronchoscope can be passed through a 4.5 mm (ID) endotracheal tube with relative ease, but the

patient will not be able to ventilate around the tube. A 5.5 mm or larger tube results in relatively little impediment to ventilation. Ultrathin instruments may be passed through smaller endotracheal tubes (3.0 mm or 3.5 mm tubes with 2.8 mm scopes and 2.5 mm tubes with 2.2 mm scopes). When using this approach make sure that the patient has a bite block between the teeth.

Insertion through Tracheostomy Tube

In patients with a tracheostomy tube, the bronchoscope may be inserted through the tube, through the stoma (after removing the tube), or through the larynx or behind and alongside the tracheal tube. As the circumstances warrant or allow. In some patients this may require temporary placement of a smaller tracheostomy or a 2.5 mm endotracheal tube through the stoma.

Insertion Via Laryngeal Mask Airway (LMA)

LMA is deployed when control of the airway, under general anesthesia, is needed, but endotracheal intubation is not required for passage of the bronchoscope.[2] The size of LMA is chosen to accommodate a FFB appropriate for the child's or infant's airway. Even small size LMA will allow passage of a 3.5 mm bronchoscope (Fig. 6.4).

The procedure provides an optimal setting with maximal patient comfort.

Fig. 6.4: Laryngeal mask airway

Beyond the Nasopharynx

As soon as the tip of the bronchoscope has passed the soft palate, the larynx should become visible. In many children there is significant amount of lymphoid tissue in the high posterior nasopharynx, and the passage beyond the choanus occasionally has to be made essentially blindly. The bronchoscope should be kept away from the posterior pharyngeal wall, and passed along the soft palate. After gaining some experience, it comes quite naturally. More lymphoid tissue may be seen at the base of the tongue, which often pushes the epiglottis posteriorly, hiding the rest of the larynx. It is better to spray the larynx with a bit more of local anesthetic when one first visualizes to prevent gagging and coughing. It requires several minutes after application of topical anesthesia (lignocaine) before the larynx becomes completely anesthetized, the delay is essential to ensure adequate anesthesia.

It is often possible to complete an adequate examination of the larynx and subglottic space without

having to enter the trachea. However, unless there is a very good reason not to enter the trachea it is recommended that a complete examination of the upper and lower airways should be done.[3] Repositioning the patient's head (flexing or extending the neck) may help to get a better angle of view. Because of the angles involved and flexible nature of the bronchoscope, you will occasionally not be able to obtain a satisfactory view of the immediate subglottic space, especially the posterior commissure. In such cases rigid laryngoscope may be needed.

When the larynx is adequately anesthetized, you are ready to pass through the glottis. Position the tip of the scope in the midline, just above the anterior commissure, flex the tip of the scope to reach this point. Then as the patient breathes in, decisively pass the instrument through the glottis, moving the tip posteriorly as you do so. The bronchoscope should be passed at least 2 cm into the trachea on the first passage. This is to avoid having the patient cough and hit the cords or other laryngeal structures on the tip of the bronchoscope. The subglottic space can be examined in a leisurely way on the way out, if necessary.

Once the bronchoscope is in the trachea. It may be necessary to spray a bit more topical anesthesia on the upper tracheal mucosa or the larynx, if the patient coughs violently or retches when you enter the trachea, it indicates requirement for more local anesthesia. Immediately instill approximately 1ml of solution

through the bronchoscope and then withdraw the tip of the scope to above the larynx. Wait a few minutes before trying again. Remember, total dose of lignocaine used should not exceed 5-8 mg/kg (1% solution carries 10 mg/ml).

EXAMINATION OF THE LOWER AIRWAYS

The first priority on entering the lower airway is to assess the patient's status. Quickly check the need for additional local anesthetic, assess if the ventilation and oxygenation is adequate. Note the dynamics of the trachea with respiration and the shape of the trachea. Are the cartilages normally shaped and any evidence of external compression, if present note its location and whether it is pulsatile. Advance the bronchoscope through the trachea to the carina; avoid the wall of the trachea. Assess the state of the mucosa. Is it inflamed, edematous, or excoriated? Excessive secretions should be suctioned if there is a suction channel. While suctioning always keep in mind the patient's comfort. Do not suction for a prolonged period (suctioning too long can deflate the lungs). Sometimes thick tenacious secretions have to be suctioned vigorously.

As you advance the scope along the airways, keep the tip centered in the airway, unless you have specific need to view an area of the wall in detail. As long as you keep in view of the airway ahead centered in the eyepiece, the bronchoscope will follow easily without scraping the walls. This will not only be more efficient,

it will also reduce the possible friction and irritation of the mucosa and the probability of cough. The lower airways may be very sensitive and require additional amounts of topical anesthetic, but usually this is not required. Patients with mucosal inflammation are more likely to need additional anesthetic.

The sequence of examination of the airways is entirely elective, but in general it is wise to examine the more normal areas first. Make a systematic examination of all the lobes and segments during each examination unless there is a compelling reason not to do so. Depending on the size of the patient and which instrument is used, it may or may not be possible to visualize each segment. Visualization is more likely in larger patients. The following guidelines should be followed while using the 3.5 mm bronchoscope[3] - In infants less than 1 kg, it is usually possible to visualize each of the lobar orifices, but it is difficult and unwise to go further into to mainstem bronchi. This is usually enough, however, to rule out major anatomic anomalies and to remove large central mucus plugs. Infants between 1 and 2.5 kg are somewhat variable, but usually it is possible to see at least the basilar segments clearly. Patients larger than about 2.5 kg usually are easily examined to a segmental level in the lower lobes, the middle lobe and the lingula, but the apical segment of the right upper lobe and superior segments of the left upper lobe may be difficult to visualize. Children larger than 6-8 kg should present little difficulty in visualizing

the segmental airways of virtually all lobes, even without entering.

In patients of all ages the upper lobes are the most difficult to examine because of the extreme angulation required. Be aware that when the tip of the scope is maximally flexed, it may necessary to gently withdraw the bronchoscope in order to advance the tip towards its goal.

When using the 3.5 mm bronchoscope in children, it is quite easy to apply sufficient torque so that the tip may be directed anywhere. In larger patients, when the insertion cord is nearly completely inserted into the airway, or with larger bronchoscopes, it may be convenient to step to one side or the other of the patient's head in order to direct the scope into the opposite mainstem bronchus. After a certain level of experience and developing some skill most bronchoscopists are able to complete a thorough examination of all the lobes and segments in 30 seconds or less after crossing the glottis. Do not attempt to rush yourself during every procedure, but you should be able to perform a complete a examination in a patient who cannot ventilate with the scope in the trachea. With prior oxygenation, virtually any patient can be apneic for 30 seconds.

POST BRONCHOSCOPY CARE OF THE PATIENT

Immediately upon completion of the procedure, assess the physiological status of the patient: respiratory rate,

ventilation, heart rate, state of consciouness, etc. Patient should be kept in a recovery room, the patient can be instructed that he may swallow and cough normally, even though he may feel he cannot, because of the local anesthesia. The patient should not be allowed food or drink until the effects of the topical anesthetic has completely disappeared, usually means 30 minutes after the procedure. Initially allow clear fluids and if they are able to accept it without vomiting they should be allowed normal diet.

Respiratory distress due to stridor or bronchospasm should be appropriately treated with oxygen, nebulization and intravenous steroids as necessary.

Patients who have been sedated should be observed until they are awake enough to at least recognize their parents and swallow water without difficulty. Appropriate monitoring procedures should be continued, depending on the age of the patient and the nature and depth of sedation, the nature of the underlying medical/surgical problem and the nature of the procedure. If a transbronchial biopsy has been performed, for example, a chest X-ray should be ordered. Following diagnostic or therapeutic bronchopulmonary lavage, some patients develop a transient fever. This usually is of little consequence and is self-limiting. If a patient has had an uncomplicated procedure and has been only lightly sedated, he may be discharged shortly after the procedure.

TECHNICAL PROBLEMS DURING BRONCHOSCOPY[3,5]

Difficult Nasal Passage

Before insertion of the bronchoscope suction the nostril and posterior pharynx. If problem is encountered in entering a nostril the other nostril should be used. The nostril should be thoroughly aspirated of secretions and a topical vasoconstrictor may be used. Generally the middle meatus between the middle and lower turbinates is the path of least resistance. Looking into the patient's neck you should be able to see the light from tip of the bronchoscope. You should be able to see the light shining through the palate or the anterior part of the neck. The bronchoscope should be passed parallel to the floor of the nose and not directed towards the glabella. If the light from the tip can be seen near the glabella, it is likely that the instrument is directed in the wrong direction. If you feel you have inserted enough but are unable to see the light withdraw the scope and look around if necessary withdraw the scope completely and make certain the lens is not obstructed with thick mucus. You meet a resistance in most patients. How much pressure to be exerted comes with experience. If you are able to see the passage ahead of the scope but are having problem getting the scope to pass a tight spot – wiggle and rotate the tip as you push ahead. Try an alternate passage, i.e. the inferior meatus instead of the middle. If insertion is still difficult then use the other nostril.

Pharyngeal Hypotonia

It is usually possible to approach the larynx directly, but sometimes the epiglottis is floppy and blocks the view. Two approaches are then possible: either pass down the posterior wall in the midline until past the epiglottis (take care not to disappear into the esophagus), or pass laterally alongside the epiglottis (take care not to get lost in the pyriform sinus) and then turn medially. It may also be helpful to change the angle of the patient's head and neck (more flexion or extension). The floor of the pyriform sinus is usually a different color from the surrounding tissue; it is white, and often has a prominent microvascular pattern, so it is easily recognized.

If the patient has been sedated deeply, relaxation of the pharyngeal musculature may make the larynx very difficult to find. This is true in-patients breathing through a tracheostomy tube (and some patients with endotracheal tube). Patients in whom it is difficult to see the laryngeal structures include those with large lymphoid tissues, neurological deficit, hypopharyngeal hypotonia and those with tracheostomy. Stimulating the patient will often increase the muscle tone and make the laryngeal structures more easily visible. In a patient with a tracheostomy, simply obstructing the tube for a few breaths will result in a marked increase in inspiratory effort and usually the glottis will then become visible. Alternately an oxygen line may be attached to the suction channel of the bronchoscope and

oxygen insufflated at 1-3 L/min to distend the pharynx. While using the ultrathin bronchoscope, a suction catheter can be inserted through the opposite nostril and oxygen passed through the catheter to achieve the same result.

Difficult Laryngeal Passage

When a flexible bronchoscope is passed transnasally one must flex the tip anteriorly to approach the glottis. As the bronchoscope is advanced towards the glottis, the angulation of the tip must be constantly changed to keep the airway ahead centered in the view. Failure to retroflex the tip as the glottis is entered is a common cause of problems with the laryngeal passage. The most common problem, however, is that the patient moves or closes the glottis whenever the bronchoscope comes near. This is usually due to either inadequate sedation or inadequate topical anesthesia and can be easily remedied.

Obstruction of Airway

In almost all children larger than 3.5 kg, the 3.5 mm bronchoscope will not obstruct the glottis sufficiently to produce respiratory distress. However, one must be adequately prepared for such a situation and always be alert to such a possibility. It is necessary to be certain that the patient is ventilating well before leaving the bronchoscope in the airway for any length of time.

Thick and Excessive Secretions

The suction channel of the 3.5 mm pediatric flexible bronchoscope is only 1.2 mm in diameter and thick secretions may be difficult to be suctioned. Instillation of a small volume of saline solution may loosen the secretions and facilitate their removal. Thick tenacious, at times rubbery mucus plugs may be removed by placing the tip of the bronchoscope into the mucus plug and applying the suction continuously, while withdrawing the bronchoscope slowly. This usually removes the mucus plug along with the bronchoscope. The occasional patient with very copious secretions might have to be given glycopyrrolate. A suction catheter can be placed through the other nostril and apply intermittent suction to the posterior pharynx. Glycopyrrolate is not effective for copious secretions from the trachea and the bronchi, this has to be suctioned. Remember to use the greatest available negative pressure on the suction tube as the suction channel is usually long and narrow. Suctioning should be brief so as not to deflate the patient's lungs. As long as it is clear that there is mucus occluding the lens and the tip is not against the mucosa, in which case you will see a red color it is appropriate to suction continuously. Judicious lavage with small volumes (3-5 ml) of sterile saline may be helpful.

Nasotracheal Intubation

Nasotracheal intubation over the flexible bronchoscope has found favor for difficult situations specially in

neonates. The endotracheal tube (ET tube) is either advanced past the nares into the hypopharynx or placed all the way up on the hub of the flexible bronchoscope. The bronchoscope is then passed through the vocal cords to the midtrachea. With the carina visualized the ET tube is advanced down over the bronchoscope. Utilizing it as a guidewire, into the trachea. In an experienced hand it can be completed in 20-30 seconds.[4,5] A common pitfall in this technique is to pass the endotracheal tube into the posterior nasopharynx prior to the passage of the bronchoscope into the ET tube. This severely restricts the mobility of the tip of the bronchoscope and ability to identify the laryngeal structures. Instead the ET tube should be placed over the bronchoscope and positioned as far proximally on the insertion cord of the instrument as possible. The tip of the bronchoscope should first be passed into the carina and then the ET tube passed through the nostril and glottis into the trachea. Unless the carina is kept in view during the entire procedure, the tip of the bronchoscope may inadvertently slip into the esophagus as the ET tube is positioned. The 3.5 mm flexible bronchoscope should be used with tubes ranging from 4.5 to 6 mm in diameter, the 4.9 mm flexible bronchoscope (standard adult size with tubes of larger than 6 mm and the ultrathin flexible bronchoscope for tubes smaller than 4.0 mm.[5] (See chapter on fiberoptic intubation).

Technical Problems of the Bronchoscope

Clouding of the lens with mucus or blood: if lens is not cleared by a simple suctioning, inject 2-3 cc of sterile saline through the suction channel and suction. If this is not successful, try wiping the tip of the scope on the carina. As a last resort the bronchoscope may have to be removed the lens cleaned and reinserted.

Neonatal Flexible Bronchoscopy

With the availability of neonatal bronchoscopes with an outer diameter as little as 2.2 mm, smallest of neonates can undergo flexible bronchoscopy. There is considerable interest in direct visual assessment of the neonatal airway.[6] Most of the indications are directed towards diagnosis and assessment of the airways and of severity of the abnormalities. The newer flexible bronchoscopes have an improved suction channel and more therapeutic maneuvers may be possible including aspiration of mucus plugs, instillation of drugs and satisfactory BAL. In a study by De Blic for 201 bronchoscopies in infants, the most common indications were persistent atelectasis, unexplained episodes of cyanosis, unexplained respiratory distress, stridor. The remainder were for acute atelectasis, assessment of lung malformations and repeat bronchoscopies for re-assessment of the airways.[6] In their study of 79 infants with chest radiograph abnormalities only 15 (19%) had normal findings with 22 (28%) having either tracheal or bronchial stenosis, 7 (9%) had granuloma, 10 (13%)

had vascular compression, the remainder had tracheo- or bronchomalacia, hypersecretion and in one case, an unsuspected foreign body.[6]

Flexible bronchoscopy in neonates have a vital role in the evaluation of abnormalities of the upper airway including subglottic stenosis which compromise the respiratory status of the child in such a way that extubation from mechanical ventilation is difficult.[7] The technique of blind insertion of a catheter remains the method of choice for obtaining lung secretions for microbiology, as it is simple to perform and minimizes the compromise to the infant.

Attention is paid to sedation and analgesia and comfort of the neonate. Inspection of the lower airway should always be performed after local anesthesia of the larynx and sedation or general anesthesia of the neonate. Local anesthetic such as 2% lidocaine should be used for spraying the vocal cords. The infant must be monitored closely for any deterioration. Heart rate, oxygen saturation, blood pressure and temperature must be monitored constantly.

The bronchoscope can be inserted per nasally, through a laryngeal mask or through the tracheostomy port. Risks of complications are significantly increased in severely ill infant requiring mechanical ventilation for respiratory failure. These babies are especially prone to hypothermia and therefore a warm environment and attention to the infant's temperature is essential. In ventilated infants, analgesia should be adequate.

Benzodiazepine such as midazolam is usually used for sedation.[8]

The airway of the sick preterm infant is readily compromized with the introduction of an instrument that almost completely blocks the endotracheal tube. Video recording of the procedure is therefore necessary. The bronchoscope can be inserted and withdrawn within 10–45 seconds as tolerated by the infant and the video recording can be reviewed more closely for an accurate assessment of the findings. Close inspection of the subglottic space is essential as this is often difficult to assess given the wide angle of a flexible bronchoscope.[8]

After the procedure the infant requires close monitoring. Apnea, hypoxia and bradycardia are common and thus need to be sought and treated. For mechanically ventilated infants, blood gases are essential and the ventilatory parameters altered accordingly. Since any pre-existing laryngeal edema may be exacerbated by the procedure, the infant may require treatment with a short course of corticosteroid. Several special procedures can be performed even in small preterm infants through the working channel of the flexible bronchoscope. Interventional bronchoscopy however, is better performed using rigid bronchoscopes. Bronchoalveolar lavage although rarely done can be an important modality in neonates.

REFERENCES

1. Prakash UBS, Kato H. The flexible bronchoscope. In Prakash UBS (Ed): Bronchoscopy. Mayo foundation. 1999;71-80.
2. Nussbaum E, Zagnoev M. Pediatric fiberoptic bronchoscopy with laryngeal mask airway. Chest 2001;120:614-16.
3. Wood RE. Spelunking in the pediatric airways: explorations with the flexible fiberoptic bronchoscope. Pediatric Clin North Am 1985;31:785-99.
4. Perez CR, Wood RE. Update on pediatric flexible bronchoscopy. Pediatric clin North Am 1994;413(2):385-401.
5. Wood RE. Pitfalls in the use of flexible bronchoscope in pediatric patients. Chest 1990;97:199-203.
6. De Blic J. Bronchoscopy, In Greengough A, Roberton NRC, Milner AD (Eds): Neonatal Respiratory Disorders. London, Arnold, 1996; 89-96.
7. Barbato A, Magarotto M, Crivellaro M, et al. The use of pediatric bronchoscope, flexible and rigid, in 51 European Centres. Eur Respir J 1997;10:1761-66.
8. Midulla F, et al. Flexible endoscopy of paediatric airways. Eur Resp J 2003;22:698-708.

Chapter 7

Fiberoptic Intubation

- Praveen Khilnani
- Mritunjay Pao

In children with difficult airway or unexpected difficult intubation fiberoptic intubation may be necessary. Bronchoscopist may be frequently called to help in those situations. This discussion involves the various available techniques of fiberoptic tracheal intubation in patients with difficult airway or failed conventional endotracheal intubation.

TRACHEAL INTUBATION UNDER CONSCIOUS SEDATION

Oral Approach

The fiberoptic bronchoscope can be used for aiding intubation in cases where conventional approach is difficult or not possible due to anatomical abnormalities resulting in difficulty in visualization of the oropharynx or larynx. After intravenous sedation has been given (usually Midazolam and Ketamine), 10 percent aerosolized xylocaine is sprayed on the palate, base of the tongue, and lateral pharyngeal walls to achieve topical anesthesia of the oropharynx. In older children about 1-2 ml 4 percent xylocaine is injected through the cricothyroid membrane, to provide topical anesthesia of the larynx and upper trachea. This provides sufficient topical anesthesia for performing tracheal intubation. Alternately topical anesthesia can also be injected through the working channel of the fiberoptic scope while it is being introduced into the trachea specially in infants and younger children. The aim is to prevent coughing, swallowing, laryngeal

spasm, and excessive salivation, to facilitate fiberoptic intubation. Accidental touching of the vocal cords or entering into the trachea stimulates cough and laryngeal spasm. Effective topical anesthesia of the upper airway can also be achieved with nebulized topical anesthetics.[1]

After topical anesthesia has been applied, 3-4 minutes later and the head is positioned in the usual position of intubation, the oropharynx is suctioned, an airway intubator is placed in the mouth and the lubricated endotracheal tube is placed 4 to 5 cm inside the airway. The endotracheal tube is held with the fourth and fifth fingers to prevent premature advancement of the tube, the index finger and thumb are used to advance the fiberscope through the endotracheal tube. As the fiberscope reaches the oropharynx, the white pharyngeal surface of the airway, soft palate, and uvula will be visualized (Fig. 7.1).

As the fiberscope enters into the oropharynx its tip is turned anteriorly to expose the epiglottis and vocal cords. Extending the head at the atlanto-occipital joint and keeping the mouth closed will keep the epiglottis away from posterior pharyngeal wall. Rarely a jaw thrust or pulling the tongue forward will facilitate glottic exposure. In case the epiglottis is large and flaccid, the tip of the fiberscope can be manipulated to negotiate the tip of the epiglottis to visualize the vocal cords.

The vocal cords should be maintained in the center of the field of view of the fiberscope by manipulations

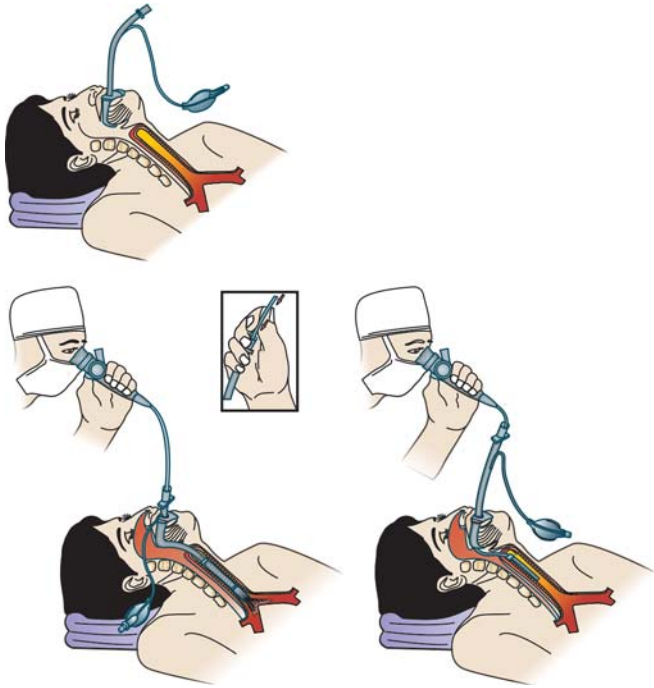


Fig. 7.1: Oral approach of fiberoptic intubation

of the tip as it is being advanced, otherwise the tip ends up in the anterior commissure or against the anterior laryngeal wall. If the view of the vocal cord is lost while advancing the scope , the fiberscope should be pulled back and the tip of the fiberscope flexed to bring it back into view. The fiberscope is then advanced through the vocal cords into the midtrachea, and the endotracheal tube is gently pushed over the fiberscope into the

trachea. While pushing the endotracheal tube over the scope care should be taken to hold the scope firmly in position, to prevent further displacement into the trachea. The tip of the endotracheal tube should be positioned 3 to 4 cm above the carina.

Problems encountered in the oral approach can be due to the sharp curve leading from the oral cavity into the larynx, impingement of the tube on the epiglottis or on the vocal cords or in the pyriform sinus.[2] Laryngospasm due to inadequate topical anesthesia may also prevent endotracheal tube advancement. In these situations, the endotracheal tube is pulled back over the fiberscope, is rotated 45° to 90° and readvanced.

Nasal Approach

For the nasal approach Xylocaine is sprayed on the nasal passage to provide topical anesthesia. Xylocaine is also sprayed through the working channel of the scope on the oropharynx and larynx as it is being introduced to achieve laryngotracheal anesthesia (2% xylocaine jelly can also be used). The endotracheal tube can be placed in the nostril first (this prevents nasal secretions from covering the lens of the fiberscope) and the fiberscope passed through it, or the endotracheal tube can be mounted over the fiberscope, which is passed first through the nostril. The well lubricated endotracheal tube is introduced through the nostril and the choanae until it reaches the posterior oropharynx (see Fig. 7.2). The fiberscope is then gently pushed forward through

the endotracheal tube, as it enters the oropharynx, the tip is usually pointed straight at the glottis. If there is difficulty in visualizing the cords, extending the head, applying a jaw thrust, or pulling the tongue forward will help in visualizing the cords. The tip of the scope is then gently negotiated and introduced into the trachea through the vocal cords. After the fiberscope has been passed into the midtrachea, the endotracheal tube can be easily pushed over the fiberscope into the trachea to a position 3-4 cm above the carina. With nasotracheal

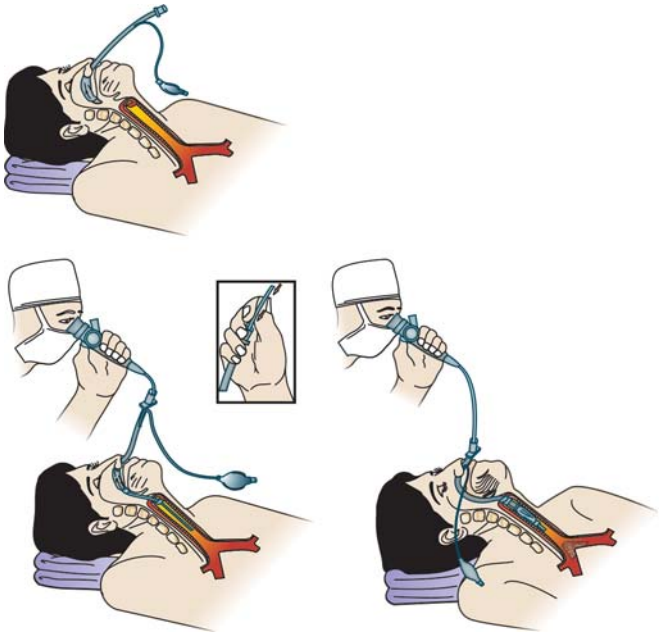


Fig. 7.2: Fiberoptic intubation by nasotracheal rante

intubation, resistance is less compared to oral approach and the incidence of the failed intubation is rare. The advantage of the nasal approach over the oral aproach is that there is no sharp turn to negotiate, and the vocal cords are usually visible from a distance.[3-5]

TRACHEAL INTUBATION UNDER GENERAL ANESTHESIA

Tracheal intubation under general anesthesia can be done with the patient either breathing spontaneously or muscle relaxed with bag and mask ventilation. This procedure requires the presence of an assistant, who is capable of maintaining oxygenation with bag and mask and also help minimize apnea time, facilitate laryngeal exposure and monitor the patient during the whole procedure. The assistant stands on the patient's left side. The assistant mounts the endotracheal tube on the well lubricated insertion cord of the scope and holds it ready to be handed to the endoscopist. Application of a jaw thrust will open the oropharynx. The disadvantages of intubation under general anesthesia are that the patient is apneic limiting the time available for the procedure and the tongue and pharyngeal tissues tend to fall back on the pharyngeal space, blocking visualization of the larynx. The problems encountered in children during orotracheal fibreoptic intubation under general anesthesia are the same as with adults. Initial ease of bronchoscopy is not always followed by easy tracheal intubation, there may

be prolonged bronchoscopy and failed intubations. Manipulation of the tracheal tube can lead to successful tracheal intubation and resistance to the tube is more common in smaller children.[6]

Fiberoptic Intubation Using an Endoscopy Mask

A modified anesthesia mask adapted for fiberoptic intubation is used to facilitate intubation by the orotracheal route. A large endoscopy port is (22 mm in diameter) is present in the middle of the mask, which allows all sizes of pediatric tracheal tubes to pass. This port has an elastic rubber membrane, which allows air tight manipulation of the scope, to allow ventilation during the procedure. A ventilation port is present in the side to facilitate ventilation.[7-9] After anesthesia has been administered, the patient is preoxygenated using the mask. The oropharynx is suctioned, and an intubating airway is placed inside the mouth. An appropriate sized endotracheal tube is placed (after removing the adapter) on the fiberscope. The insertion cord of the scope is advanced through the rubber diaphragm of the endoscopy port into the intubating airway, the vocal cords are visualized, and the scope is inserted through the cords into the trachea.[7,8] Then endotracheal tube is gently pushed over the scope through the endoscopy port and intubating airway into the trachea. The fiberscope and the endoscopy mask is now removed, while keeping the endotracheal tube in place taking care to avoid displacement. The

endotracheal tube adapter is then connected to the ET tube. This technique requires an assistant who provides anesthesia, provides mask ventilation and also monitors the patient.

Modified Endoscopy Mask Technique

Fiberoptic intubation through a modified anesthesia mask may cause loss of the continuity of the ventilation circuit when the endotracheal tube crosses the endoscopy port and this technique may also cause damage to the instrument. To avoid both of these shortcomings, a modified technique has been described.[10] A bronchoscopy swivel adapter is attached to the endotracheal tube adapter (its 15 mm side arm is blocked with tape). The endotracheal tube is then attached loosely to the adapter, lubricated and passed through the diaphragm of the endoscopy mask port by about 10 cm.

Anesthesia is induced with a regular anesthesia mask. After achieving anesthesia the mask is removed, an intubating airway is placed, and the oropharynx is suctioned. The endoscopy mask is mounted with the endotracheal tube over the face, with the distal 2 inches of the endotracheal tube entering inside the airway. Anesthesia is continued with this set up. With this technique the ventilation circuit remains closed. The fiberscope is advanced through the swivel adapter and endotracheal tube into the oropharynx and into the trachea. The endotracheal tube is advanced over the

fiberscope into the trachea. The fiberscope and two adapters are now removed, leaving the endotracheal tube in place. The endoscopy mask is quickly removed from the endotracheal tube, then the endotracheal tube adapter is reattached to the endotracheal tube.

Intubation Using the Nasal Airway

Nasal airway can be used to maintain oxygenation and anesthesia, while performing fiberoptic intubation through both nasal and orotracheal techniques. This technique provides adequate time for unhurried and safe fiberoptic intubation. For the orotracheal intubation a binasal airway is inserted after application of local anesthesia and it is attached to the C-circuit breathing system. An intubating airway is placed in the oropharynx and the endotracheal tube mounted on the lubricated fiberscope is inserted through the airway into the trachea. For nasopharyngeal intubation a single nasal airway is inserted in one nose and connected to the C-circuit and the intubation is done through the other nasal passage.[1,12,13]

Confirmation of Endotracheal Tube Position

Although fiberoptic intubation makes intubation under direct vision possible, chances of esophageal or endobronchial intubation do exist. Unrecognized esophageal intubation has been related to cerebral damage and increased mortality.[14,15] The chances of esophageal intubation is increased in the presence of

excessive secretion, abnormal airway anatomy or uncooperative patients. The lumen of the esophagus can be recognized by its flat wall, with the anterior and posterior walls usually touching each other. If tracheal rings cannot be identified, the fiberscope should be advanced till the carina is visualized to confirm tracheal placement. The presence of tracheal bifurcation will exclude the possibility of esophageal intubation. The endotracheal tube may get dislodged inadvertently from the trachea while the fiberscope is being withdrawn or while the endotracheal tube is being taped to secure it. One should confirm tube position and its relation to the carina with the fiberscope after intubation and taping it in position. Proper placement of tube should be further confirmed clinically by auscultation of apical and midaxillary for bilaterally equal air entry, looking for symmetric bilateral movement of the upper chest wall. One should auscultate the epigastrium for esophageal placement. Endtidal CO_2 measurement if available, is a reliable for confirming tube placement.[16,17]

COMPLICATIONS

Complications encountered during fiberoptic intubations are limited to laryngospasm due to inadequate topical anesthesia, pain and/or hematoma at the translaryngeal injection site, gagging and/or vomiting, and mild epistaxis in those undergoing nasotracheal intubation. If the fiberscope enters it may relax the cricopharyngeus muscle and facilitate

regurgitation of gastric contents into the oropharynx if the esophagus contains gastric juice. Respiratory depression and hypoxemia are relatively common with intravenous sedation, major respiratory depression necessitating assisted ventilation is rare. Monitoring oxygen saturation using the pulse oximeter, routine administration of oxygen during the procedure will prevent hypoxia and major respiratory depression. The possibility of barotrauma to lungs should be kept in mind if the fiberscope is advanced through a narrowed airway, limiting the oxygen escape from the lungs. Laryngospasm is likely if poorly anesthetized vocal cords are touched with the fiberscope.

REFERENCES

1. Southerland AD, Sale JP. Fiberoptic awake intubation: a method of topical anaesthesia and orotracheal intubation. Can Anaesth Soc J 1986;33:502-04.
2. Stiles CM, Stiles QR, Denson JS. A flexible fiberoptic laryngoscope. JAMA 1972;221:1246-47.
3. Rucker RW, Silva WJ, Worcester CC. Fiberoptic bronchoscopic nasotracheal intubation in children. Chest 1979;76:56-58.
4. Ovassapian A, Yelich SJ, Dykes MHM, Brunner EA. Fiberoptic nasotracheal intubation: Incidence and causes of failure. Anesth Analg 1983;62:692-95.
5. Blanco G, Melman E, Cuairan V, Moyao D, Ortiz-Monasterio F. Fibreoptic nasal intubation in children with anticipated and unanticipated difficult intubation. Paediatr Anaesth. 2001 Jan;11(1):49-53.
6. Hakala P, Randell T, Meretoja OA, Rintala R.Orotracheal fibreoptic intubation in children under general anaesthesia. Paediatr Anaesth 1997;7(5):371-4.

7. Patil V, Stehling LC, Zauder HL. Fiberoptic endoscopy in anesthesia. Chicago: Year Book, 1983.
8. Rogers SN, Benumof JL. New and easy techniques for fiberoptic endoscopy aided tracheal intubation. Anesthesiology 1983; 59:569-72.
9. Kitamura S, Fukumitsu K, Kinouchi K, Takada K, Taniguchi A. A new modification of anaesthesia mask for fibreoptic intubation in children. Paediatr Anaesth. 1999;9(2):119-22.
10. Ovassapian A. Fiberoptic tracheal intubation. In Ovassapian A (Ed): Fiberoptic Airway Endoscopy in Anesthesia and Critical Care Raven press (New York)1990:57-79.
11. Wangler MA, Weaver JM. A method to facilitate fiberoptic laryngoscopy. Anesthesiology 1984;61:111.
12. Lu.GP, Frost EAM, Goldiner PL. Another approach to the problem airway. Anesthesiology 1986;65:101-102.
13. Holm-Knudsen R, Eriksen K, Rasmussen LS. Using a nasopharyngeal airway during fiberoptic intubation in small children with a difficult airway. Paediatr Anaesth 2005 Oct ;15:839-45.
14. Utting JE, Gray TC, Shelley FC. Human misadvanture in anaesthesia. Can Anaesth Sac J 1979;26:472-78.
15. Keenan RL, Boyan CP. Cardiac arrest due to anesthesia: a study of incidence and causes. JAMA 1985;253:2373-77.
16. Birmingham PK, Cheney FW, Ward RJ. Esophageal intubation : a review of detection techniques. Anesth Analg 1986;65:886-91.
17. Murray IP, Modell JH. Early detection of endotracheal tube accidents by monitoring carbon dioxide concentration in respiratory gas. Anesthesiology 1983;59:344-46.

Chapter 8

Special Procedures

• Praveen Khilnani

In this chapter ancillary procedures used during flexible fiberoptic bronchoscopy will be discussed. Ancillary procedures applicable to pediatric patients include the following:[1]

1. Bronchoalveolar lavage (BAL)
2. Endobronchial biopsy
3. Transbronchial biopsy and cytology brushing
4. Laser therapy
5. Airway dilation via balloon insufflation
6. Airway stenting
7. Bronchography
8. Segmental instillation of medication
9. Assessment of lower airways inflammation

Fiberoptic intubation is discussed in a separate chapter (see chapter 7). Only commonly done procedures will be discussed in detail.

Bronchoalveolar Lavage (BAL)

Bronchoalveolar lavage is commonly used for diagnostic purposes. In children standard of technique as well as normal values are yet to be defined.

Bronchoalveolar lavage (BAL) is a safe and sensitive technique for investigating infectious causes of respiratory disease. In the immunocompromized child BAL is used to obtain samples for microbiology and cytology studies.[2] Quantitative bacterial cultures of BAL have been used to diagnose pneumonia in immunocompromized and immunocompetent patients. When BAL with <1% squamous epithelial cells was

analyzed, the finding of >105 colony-forming units of a single bacterial species per ml of BAL was correlated with bacterial pneumonia in comparison with normal subjects.[3-5] In immunosuppressed patients with diffuse lung infiltrates, *P. carinii* can be identified in BAL with a sensitivity of upto 85 percent.[6-9] Based on response to therapy or histology findings on biopsy or autopsy, the absence of *P. carinii* in BAL in immunosuppressed patients has a negative predictive value of >90 percent.[8-10] In these patients, the sensitivity for detecting *M. tuberculosis* is upto 95 percent. The negative predictive value of absence of *M. tuberculosis* on BAL is > 90 percent.[8,9] The role of BAL in monitoring interstitial diseases and chronic infective disorders such as tuberculosis and cystic fibrosis is controversial and undefined for routine use.[11-14] The dominant role of transbronchial biopsy (TBB) is in interstitial lung disease and immunocompromized individuals including lung transplant recipients.[2,15] BAL is also indicated in patients with suspected aspiration and evaluation of recurrent or persistent pulmonary infiltrates. The analysis of BAL fluid is also useful for the diagnosis of various lung diseases especially ideopathic pulmonary fibrosis (IPF), Sarcoidosis, and hypersensitivity pneumonitis. Alveolar macrophages are >95 percent and lymphocytes <5 percent in healthy patients. In sarcoidosis, (hypersensitivity pneumonitis and active phase IPF) lymphocytes increase to 30-80 percent. T4/T8 ratio decreases due to increase in number of T8 cells in

hypersensitivity pneumonitis. Over all activated T lymphocytes increase in hypersensitivity pneumonitis and sarcoidosis. B lymphocytes increase significantly in IPF and collagen vascular diseases. Liquid fraction can be assessed for IgG, ACE, CEA, fibronectin, leukotriene, prostagladin E2, F2alpha, thromboxane B2, histamine, and serotonin, however, their pathophysiological role is not clear yet.

*Collection of bronchoalveolar lavage fluid:*These methods are divided in two groups—*Bronchial lavage (BL)* and *bronchoalveolar lavage (BAL).*

The former instills saline into the peripheral airways which contains bronchioles and alveoli. The analysis of BAL is also useful.

Technique for BAL (Fig. 8.1)

Bronchoalveolar lavage (BAL) is performed[16,17] by alternately instilling saline into and aspirating it from a distal airway. To limit the area of lung lavaged (increasing specificity and reducing risk and discomfort to the patient), the delivery system is gently wedged into the selected bronchus.

BAL is performed with a flexible bronchoscope, in which case the tip of the bronchoscope itself is wedged into the bronchus. Saline is then instilled through the suction port. Alternatively, a catheter can be passed through a rigid bronchoscope and wedged into position. BAL can also be performed blindly by passing a catheter through an endotracheal or tracheostomy tube.[18] When

a catheter is used, it should have a hole only at the tip. BAL can be performed in a specific area of the lungs, based on radiographic findings. If there is diffuse disease, however, it is advantageous to wedge the bronchoscope into the lingula or right middle lobe bronchus. These bronchi are relatively long and horizontal; the tip of the bronchoscope is more likely to remain wedged into these bronchi during coughing than in a lower lobe bronchus. When the bronchoscope does not remain wedged, saline may spill into other bronchi, producing coughing and possibly respiratory distress.

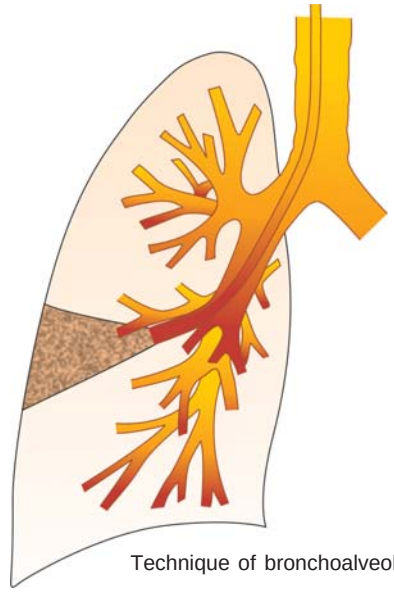


Fig. 8.1: Bronchoalveolar lavage

With the delivery system gently wedged into the bronchus, saline is instilled and immediately with drawn. The fluid may be instilled with a syringe, or by gravity from a reservoir. The fluid may be withdrawn by hand suction with a syringe, or the fluid may be aspirated into a trap with regular suction. If too much negative pressure is used during withdrawal, the bronchus will collapse, thus preventing efflux of the fluid. Fluid return is also impaired if the patient is not breathing spontaneously. Normally, between 40 and 60 percent of the instilled fluid is recovered; the remainder is absorbed over a few hours. The volume of saline used in each aliquot, and the number of aliquots used, varies considerably. In an attempt to standardize technique, protocols have been developed for BAL in adults; most utilize 3 aliquots of 100 ml or 5 aliquots of 50 ml.[15] No critical analysis of the appropriate volumes for pediatric patients has been published. Volumes used in published pediatric series are variously reported to be 1 to 3 ml/kg, 10 ml regardless of patient size, or a fraction of estimated functional residual capacity (FRC).

For clinical purposes, the precise volume used is probably of little relevance, as the primary application in children is the detection of infectious agents. The first aliquot returned is relatively enriched in fluid from the surface of conducting airways, and may have a higher percentage of inflammatory cells. Some bronchoscopists therefore discard this fraction. However, for diagnostic purposes it makes less difference since the bronchial

surface fluid will be eventually be washed into the alveolar spaces and thus "contaminate" the subsequent aliquots.

Interpretation of BAL Findings

BAL fluid should routinely be processed (promptly) for microbiologic studies and cytology. A minimum evaluation would include bacterial (preferably, quantitative) culture and an estimate of the relative proportions of different cell types (neutrophils, macrophages). Depending on the purpose of the BAL, the evaluation may be expanded to include cultures or rapid diagnostic studies for other infectious agents such as viruses or mycobacteria, cell counts and special cytologic stains, lymphocyte subset enumeration, and measurement of soluble constituents such as albumin and inflammatory mediators.

The most basic evaluation of a BAL specimen is to determine whether there is evidence of bacterial infection, as evidenced by increased numbers/percent ages of neutrophils and by significant numbers of pathogenic bacteria. The total number of cells obtained by BAL will vary with the technique (increased aliquot numbers or use of a larger bronchoscope, which would wedge in a more proximal bronchus, will increase cell numbers) as well as with the disease state. In general, cell numbers in normal children will range between 100, 000 and 250, 000 cells/ml. Normal BAL fluid contains less than 5 percent neutrophils (usually, only

1 to 2%).[18-20] Patients with an active bacterial infection may have up to 95 percent neutrophils, and rarely less than 25 percent. Patients with bacterial infection often have bacterial forms visible in the cytoplasm of neutrophils recovered in BAL.[21] A count of lymphocyte subsets may be of value in some clinical situations.[18]

Opinions vary as to what numbers of bacteria constitute adequate evidence of infection. For common bacterial species such as *Staphylococcus aureus, Haemophilus influenzae,* and *Streptococcus pneumoniae,* concentrations of more than 100,000 organisms/mI of BAL fluid[22] in association with significant numbers of neutrophils is a good evidence. Numbers in excess of 500,000 organisms/ml are common in clear-cut bacterial infection. However, the interpretation is not always straightforward, especially if significant numbers of "oral flora" are also recovered. In pediatric patients, it is possible to obtain BAL specimens that are sterile, but the majority will have at least some oral flora even if there are no pathogens.

When small numbers of pathogenic organisms are found, the interpretation may be difficult, unless the potential pathogens are never present in a normal host. An example would be *Pneumocystis carinii*. In any case, the interpretation must be made in the context of the patient's clinical situation.

Normally, 90 to 95 percent of the nonepithelial cells in BAL are alveolar macrophages. Eosinophils are rare in normal subjects; significant numbers suggest an

allergic state or perhaps a foreign body reaction. Large numbers are seen in eosinophilic pneumonia. Sarcoidosis and other interstitial lung diseases, as well as tuberculosis, are associated with increased percentages of lymphocytes. Lipid-laden macrophages are seen in patients with aspiration (although the sensitivity and perhaps specificity may be relatively low).

Patients with chronic inflammation may have increased lipid staining of their macrophages; calculation of a "lipid index" may increase the sensitivity and specificity of the study.[23] Hemosiderin-laden macrophages are seen in patents withi recent intra-pulmonary bleeding or hemosiderosis.

Measurement of soluble substances in BAL fluid clinical interpretation (i.e. inflammatory mediators) is currently an investigational procedure. Similarly, polymerase chain reaction (PCR) and other techniques to detect specific substances in very small quantities are currently employed largely in experimental settings. Ultimately, such measures may be helpful in diagnosis.

Endobronchial Biopsy

Endobronchial biopsy is a safe procedure for the diagnosis of tuberculosis and other infectious or granulomatous disorders. It is also a well-established clinical technique for obtaining ciliated cells for the diagnosis of primary ciliary dyskinesia. Research applications for endobronchial mucosal biopsies include

studies on bronchial inflammation in patients with asthma or cystic fibrosis.[24,25] Biopsy of superficial airway structures can be performed with a brush or forceps.[25] The 4.9 or 5 mm instrument with its 2.2 mm working channel allows a protected brush to be used. This risk can be minimized when the brush is left protruding from the bronchoscope or even better is hidden in the tip of the scope while the instrument is withdrawn (protected brush specimen). Subsequently, agitating the brush in appropriate medium dislodges the cells. Biopsies should be taken from segmental subcarinas, which are sharper and thus allow a better grip by the forceps. A routine chest radiograph is not necessary after endobronchial biopsy. The material can be prepared for electron microscopy and immunohistochemistry as well as standard histopathology.[25]

Transbronchial Biopsy

Transbronchial biopsy (TBB) is done to obtain peripheral lung tissue for diagnostic studies including histopathological examination and for microbial cultures. TBB has an established place in lung transplant recipients: it has a high sensitivity and specificity, and represents the gold standard for diagnosing acute rejection and delineating opportunistic infection;[26] it is of less use in diagnosing chronic rejection (bronchiolitis obliterans).[27] It has a controversial role in patients with human immunodeficiency virus (HIV) infection to delineate noninfective pulmonary pathology, after bone

marrow transplantation to diagnose obliterative bronchiolitis, and in patients with interstitial lung disease.[28]

Prior to TBB a plain chest radiograph, a full blood count including platelet count, and a coagulation screen should be done.

The procedure is carried out under deep sedation or general anesthesia. Fluoroscopy is mandatory for accurate positioning of the biopsy forceps in order to get the maximum yield from sites of radiographic abnormality and to minimize the risk of pneumothorax. The forceps (either alligator jaw or cupped head biopsy forceps) are introduced through the bronchoscope and advanced under fluoroscopic screening until resistance is felt (Fig. 8.2). Then the forceps are withdrawn 1–2 cm, the jaws of the forceps are opened and wedged into the lung tissue after rapidly advancing; some workers

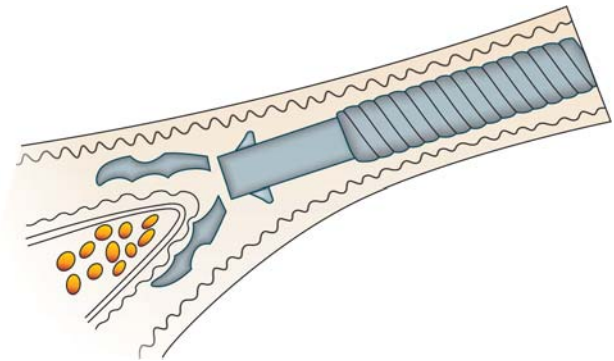


Fig. 8.2: Transbronchial biopsy

do so after advancing and withdrawing the forceps for two to three times.[29]

Subsequently, the forceps are closed and briskly withdrawn. After completion, a small saline lavage and visualization of the bronchial tree should be performed to ensure hemostasis. A chest radiograph 2-4 hours later is mandatory to rule out a slowly developing pneumothorax. Only one lung should be sampled on a same occasion in order to prevent the occurrence of bilateral pneumothoraces. The middle lobe and the lingula are avoided if at all possible to reduce the risk of pneumothorax. At least three biopsies should be obtained for microbiological and histological studies. In order to achieve optimal specimens, the application of negative pressure during fixation of the biopsy is recommended.

However, especially in children>2 years, it may be difficult to obtain specimens containing sufficient lung parenchyma. To circumvent this problem in infants and small children, a new technique has been developed.[30] With this "indirect" technique, a 2.2 mm bronchoscope is used to direct a plastic catheter visually into the desired lung segment. Subsequently, the suction catheter acts as the working channel through which larger biopsy forceps can be introduced. However, experience with this technique is limited.

The major complication of TBB is a pneumothorax with an incidence of >3 percent.[29] Small hemorrhages often occur but resolve either spontaneously or after

lavage with saline. If bleeding is profuse and persistent; instillation of adrenalin solution (1:10, 000) may be necessary. Other complications include transient pyrexia and transient dyspnea. Thus, it is recommended that patients should be observed overnight following the procedure.

Laser

Usually, rigid bronchoscopes are used to perform endoscopic laser resection. However, airway lesions such as subglottic hemangiomas (Fig. 8.3) and acquired tracheal or bronchial stenosis (Fig. 8.4) can be successfully managed even in infants with laser treatment using flexible endoscopes.[31,32] There are some drawbacks of the latter technique compared to rigid bronchoscopy:

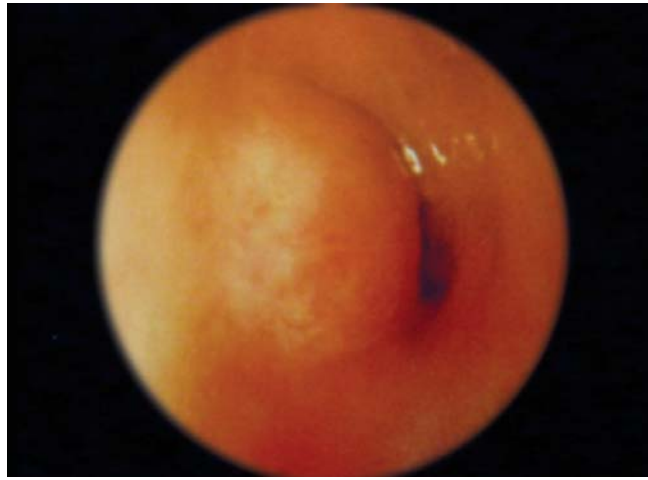


Fig. 8.3: Subglottic hemangioma

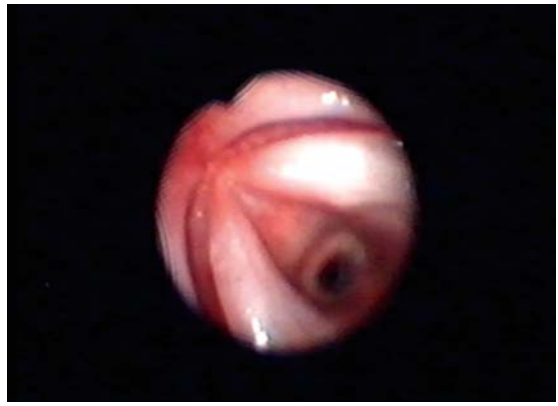


Fig. 8.4: Tracheal stenosis

1. The procedure is more time-consuming,
2. The inability to perform mechanical resection may result in incomplete resolution of the obstruction and may necessitate more laser energy to vaporize the lesions,
3. Complications such as bleeding are difficult to control, and
4. Flexible endoscopes are easily damaged.

Bronchography

Bronchography can be performed by injecting contrast material through the working channel of the flexible bronchoscope in order to delineate anatomic abnormalities.[33] Various advantages of using fiberoptic scope for bronchoscopy versus Nelaton and Metra catheters are as follows:

1. Simultaneous observation of intratracheal lesions is possible.
2. Secretions which inhibit the procedure can be easily eliminated.
3. Instillation of anesthetic agent via the channel is possible.
4. Procedure time is reduced.
5. Target bronchus can be examined selectively.

The flexible instruments can be situated in the area of interest, thus less contrast material is needed. In addition, some of the contrast can be suctioned back at the end of the procedure, thus decreasing the risks of atelectasis and chemical pneumonitis.

Fiberoptic Intubation (see Chapter on Fiberoptic Intubation)

Endoscopic intubation of a difficult airway may be accomplished with the aid of a flexible bronchoscope even in preterm neonates (e.g. in patients with Pierre Robin syndrome, craniofacial trauma, croup, epiglottitis (Figs 8.5 and 8.6).[34] With ultrathin instruments, intubation may be performed with endotracheal tubes as small as 2.5 mm.

Drug Application

Bronchoscopic administration of surfactant may represent an effective method of delivery in acute respiratory distress syndrome.[35] Furthermore, in persistent atelectasis unresponsive to medical therapy

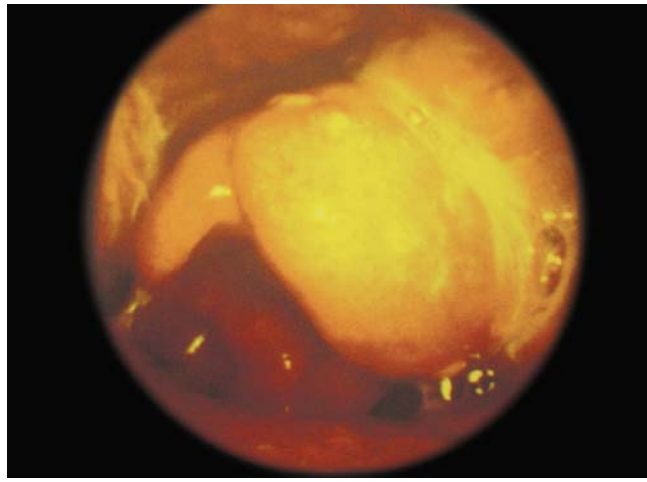


Fig. 8.5: Epiglottitis

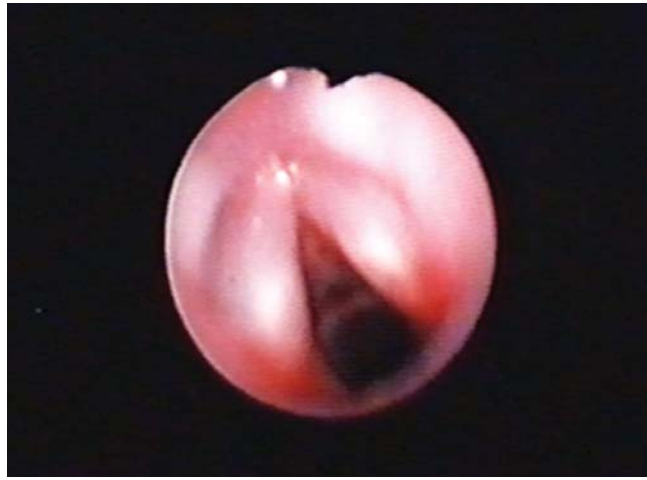


Fig. 8.6: Croup

bronchoscopic instillation of recombinant human DNase has been found to be useful.

Closure of Bronchopleural Fistulae

FB with the delivery of methacrylate adhesive to a bronchopleural fistula may be a reasonable alternative to operative closure when the operative risk is great.[36] As the glue should not come into direct contact with the bronchoscope, it should be injected through a catheter placed through the working channel of the instrument.[37]

Removal of Foreign Bodies

Airway foreign bodies are best removed by a controlled rigid bronchoscopy performed under anesthesia, although case reports are available where basket introduced through the flexible bronchoscope suction channel has been used to successfully remove the foreign bodies lodged in the airways.[38] This procedure is, however, difficult and the procedurist must have an availability of a back-up facility of a rigid bronchoscope in case of difficulty. Ideally a combination of rigid bronchoscopy and flexible bronchoscopy to visualize small distal foreign body fragments, as well as to check for adequate foreign body removal works out well at our institution. Flexible bronchoscope can also be introduced via rigid bronchoscope to visualize distal airways where rigid bronchoscope may not reach. Common foreign objects reported from India which

may be inhaled are groundnut seeds, tamarind seeds, chikoo seeds, metallic pins, pea-nuts, chana, whistle of toys, different kind of fruits, rathi seeds.[39]

AIRWAY STENTS[40-46]

Definition

Airway stents, similar to vascular stents, are devices designed to keep tubular structures open and stable. Airway stents are intended for placement in the central tracheobronchial tree. Depending on the design, they may be placed with either flexible or rigid bronchoscopes.

Equipment

Numerous different stent designs have been developed to allow for adaptation to the individual anatomic requirements and operator preference. Depending on the manufacturing material (silicone, metal, or hybrid design), flexible or rigid endoscopic equipment is required. Delivery devices specific for the individual stent are necessary and frequently accompany the actual device (such as delivery catheters). It is desirable to have fluoroscopic capability to be available.

Personnel

Two assistants are required. One should be solely monitoring the patient after administering the sedation. Other assistant should assist the operator. Patient will require adequate sedation in combination with local anesthesia.

Technique

In case of airway obstruction, an appropriate lumen needs to be reestablished before placing a stent. This can be achieved by a variety of methods depending on the type of obstruction. The choice of stent depends on the underlying lesion to be treated, dedicated operator preference and resource availability.

Proper stent sizing is critical and can be achieved by reviewing CT images, balloon catheter sizing and other methods, including relying on the experience of the dedicated operator. The stent length should exceed the length of the lesion to some degree to ensure patency. If stents are chosen too small in diameter, they may migrate; if they are chosen too large, they may not open or may cause stress on the airway wall.

Indications

Indications for stents in the central airways are expanding. Conditions responsive to stenting under the appropriate circumstances are intrinsic airway obstruction from benign or malignant diseases, extrinsic airway compression such as tumors or other structures within the chest, sealing of airway fistulas and, in selected cases, tracheobronchomalacia. In addition to the contraindications for flexible or rigid bronchoscopy, stent placement, like other endobronchial therapeutic interventions, should be avoided if nonviable lung is present beyond the obstruction.

As long-term experience with metallic stents is limited compared to silicone prosthesis, many authorities prefer the primary consideration of removable stents in benign disorders.

Risks

In addition to the risks associated with rigid or flexible bronchoscopy, stents may migrate and cause infection. Granuloma formation, breakage of metal fibers, hemoptysis, and airway obstruction due to impaction or granulomas and pain are potential risks. Mortality due to stent placement is rare though in pediatrics the experience is limited. Potential for displacement of stent and airway obstruction is a major threat, so proper placement , sizes as well as loosening fit with time due to airway growth is very important .

Training Requirements[1]

Dedicated operators performing airway stenting should have extensive experience in flexible and rigid bronchoscopy and management of central airway lesions.

Trainees should perform at least 20 procedures in a supervised setting to establish basic competency. To maintain competency, dedicated operators should perform at least 10 procedures per year. In order to make the best choice for the individual patient, the dedicated operator should be proficient in the placement of both flexible and silicone stents.

Newer Applications of Bronchoscopy

Some of the newer applications of flexible fiberoptic bronchoscopy include incorporation of LMA during bronchoscopy, guiding surgery after thermal injury or traumatic tear of a major bronchus, deployment of an ultrathin bronchoscope in the neonatal intensive care unit for inspection of airway patency and tube position in extremely premature infants, and evaluation or adjustment of tracheostomy tubes. The cytologic and microbiologic results of BAL are of particular importance in the diagnosis of pulmonary infiltrates in immunocompromized children, those with pulmonary hemosiderosis, and those with gastroesophageal reflux disorder. Persistent or recurrent stridor and unexplained chronic cough or wheezing with pulmonary infiltrates constitute the most common indications for bronchoscopy. In those with stridor or abnormal phonation, bronchoscopy has been shown to reveal subglottic narrowing or enlarged adenoidal tissue, a normal larynx or laryngomalacia. The utilization of the ultrathin FFB (1.8 or 2.2 mm in diameter) provides an appreciation of the dynamic state of the upper airways in their natural state, devoid of disruption from general anesthetic agents or the oral approach with the rigid bronchoscope, particularly helpful in patients with laryngomalacia and vocal cords dysfunction. Patients on BIPAP for tracheo-bronchomalacia, BIPAP levels can be titrated to prevent significant dynamic collapse of the airway.[5]

The approach to patients with extensive lobar atelectasis, ventilation-perfusion mismatch, and hypoxia remains a source of debate. The superiority of interventional bronchoscopy to that of conventional airway clearance techniques remains unsettled. In contrast, patients with massive atelectasis who are already intubated and mechanically ventilated should benefit from targeted removal of peripheral secretions or plugs under direct vision because blind conventional suctioning may reach secretions situated only above the carina. Restoration of lost functional volume with improvement of the ventilation-perfusion relationship, reduction of the intrapulmonary shunt, and improved gas exchange should be the main objectives of such intervention.

The diagnostic application of bronchoscopy in hemoptysis has been previously reported. It has long been concluded that flexible fiberoptic bronchoscopy is practically useless in severe cases of hemoptysis. The source of bleeding cannot be visualized adequately because blood obscures the working field and the specimens extracted during active bleeding have minimal, if any, clinical value.

Endobronchial Ultrasound

This is a recently introduced technology whereby the ultrasound probe applied to tip of the bronchoscope allows assessment of proximity and density of the lesion such as cystic lesions, vascular ring, lymph nodes, granulomas can be assessed and appropriate diagnostic technique such as transbronchial biopsy or their methodology can be applied.

REFERENCES

1. Ernst A, Gerard A, Silvestri GA, Johnstone D. American College of Chest Physicians Interventional Pulmonary Procedures: Guidelines from the American College. Chest 2003; 123;1693-1717
2. Wood RE, Prakash UBS. Pediatric flexible bronchoscopoy. In: Prakash UBS (Ed): Bronchoscopy, 1st edn. New York, Raven Press, 1994;345-46.
3. Kahn FW, Jones JM. Diagnosing bacterial respiratory infection by bronchoalveolar lavage. J Infect Dis 1987;155:862-69.
4. Kirkpatrick MB, Bass JBJ. Quantitative bacterial cultures of bronchoalveolar lavage fluids and protected brush catheter specimens from normal subjects. Am Rev Respir Dis 1989; 139:546-48.
5. Nussbaum E. Pediatric fiberoptic bronchoscopy: Clinical experience with 2,836 bronchoscopies. Pediatr Crit Care Med 2002: 3(2):171-76.
6. Bye MR, Bernstein L, Shah K, Ellawie M, Rubinstein A. Diagnostic bronchoalveolar lavage in children with AIDS. Pediatr Pulmonol 1987;3:425-28.
7. Frankel LR, Smith DW, Lewiston NJ. Bronchoalveolar lavage for the diagnosis of penumonia in the immuno-compromized child. Pediatrics 1988;81:785-88.
8. Martin WJ, Smith TF, Brutinel W, M Cockwill FR, Dauglos WW. Role of bronchoalveolar lavage in the assessment of opportunistic pulmonary infections: Utility and complications. Mayo Clin Proc 1987;62:549-57.
9. Stover DF, Zaman MB, Hajdu SI, Lange M, Gold J, Armstrong D. Bronchoalveolar lavage in the diagnosis of diffuse pulmonary infiltrates in the immunosuppressed host. Ann Interm Med 1984;101:1-7.
10. Williams D, Yungbluth M, Adams G, Glass-roth J. The role of fibreoptic bronchoscopy in the evaluation of immunocompromised host with diffuse pulmonary infiltrates. Am Rev Res Dis 1985;131:880-85.

11. Godfrey S, Avital A, Maayan C, Rotschild M, Springer C. Yield from flexible bronchoscopy in children. Pediatr Pulmonol 1997;23:261-66.
12. Pattishall EN, Noyes, BE, Orienstein DM. Use of bronchoalveolar lavage in immuno-compromized children with pneumonia. Pediatr Pulmonol 1988;5:1-5.
13. Barlogh K, McCubbin M, Weinberger M, Smits W, Ahrens R, Fick R. The relationship between infection and inflammation in the early stages of lung disease from cystic fibrosis. Pediatr Pulmonol 1995;20:63-70.
14. Armstrong DS, Grimwood K, Carlin JB, Carzino R, Olinsky A, Phelan PD. Broncho-alveolar lavage in infants with cystic fibrosis. Pediatr Pulmonol 1996;21:267-75.
15. Marquette CH, Martinot A, Brichet A. Interventional bronchoscopy. Pediatr Pulmonol 1999;19(Suppl):125-29.
16. Reynolds HY. State of the art:bronchoalveolar lavage. Am Rev Respir Dis 1987;135:250-63.
17. Baughman RP. Bronchoalveolar lavage. St Louis, Mosby-year book, 1992.
18. Koumborlis AC, Kurland G. Nonbronchoscopic broncho-alveolar lavage in intubated mechanically ventilated infants:technique, efficacy and applications. Pediatr Pulmonl1993;15:257-63.
19. Midulla F, Villani A, Merolla R, et al. Bronchoalveolar lavage studies in children without parenchymal disease:cellular constituents and protein levels. Pediatr Pulmonl 1995;20:112-18.
20. Riedler J, Griggs J, Stone C, et al. Bronchoalveolar lavage cellularity in healthy children. Am J Respir Crit Care Med1995;152:163-68.
21. Sole-Violean J, Rodriguez de Castro, Rey A, et al. Usefulness of microscopic examination of intracellular organisms in lavage fluid in ventilator associated pneumonia. Chest 1994;106:889-94.
22. Thorpe JE, Baughman RP, Frame PT, Wesseler TA, Staneck JL. Bronchoalveolar lavage for diagnosing acute bacterial pneumonia. J Infect Dis 1987;155:855-61.

23. Colombo JL, Hallberg TK:Recurrent aspiration in children:lipid laden alveolar macrophage quantitation. Pediatr Pulmonol 1987;3:86-89.
24. Payne DN, Rogers AV, Adelroth E, et al. Early thickening of the reticular basement membrane in children with difficult asthma. Am J Respir Crit Care Med 2003;167:78-82.
25. Bush A, Pohunek P. Brush biopsy and mucosal biopsy. Am J Respir Crit Care Med 2000;162:423-26.
26. Whitehead B, Scott JP, Helms P, et al. Technique and use of transbronchial biopsy in children and adolescents. Pediatr Pulmonol 1992;12:240-46.
27. Scott JP, Higenbottam TW, Smyth RL, et al. Transbronchial biopsies in children after heart-lung transplantation. Pediatrics 1990; 86: 698-702.
28. Fan LL, Kozinetz CA, Wojtezak HA, Chatfield BA, Cohen AH, Rothenberg SS. Diagnostic value of transbronchial, thoracoscopic, and open lung biopsy in immunocompetent children with chronic interstitial lung disease. J Pediatr 1997;131:565-69.
29. Midulla F, et al. Flexible endoscopy of paediatric airways. Eur Resp J 2003 Oct;22(4):698-708.
30. Mullins D, Livne M, Mallory GB Jr, Kemp JS. A new technique for transbronchial biopsy in infants and small children. Pediatr Pulmonol 1995;20:253-57.
31. Azizkhan RG, Lacey SR, Wood RE. Acquired symptomatic bronchial stenosis in infants: successful management using and argon laser. J Pediatr Surg 1990;25:19-24.
32. Bagwell CE. CO_2 laser excision of paediatric airway lesions. J Pediatr Surg 1990;25:1152-56.
33. Bramson RT, Sherman JM, Blickman JG. Pediatric bronchography performed through the flexible bronchoscope. Eur J Radiol 1993; 16: 158-61.
34. Finer NN, Muzyka D. Flexible endoscopic intubation of the neonate. Pediatr Pulmonol 1992;12:48-51.
35. Nakamura CT, Ripka JF, McVeigh K, Kapoor N, Keens TG. Bronchoscopic instillation of surfactant in acute respiratory distress syndrome. Pediatr Pulmonol 2001;31:317-20.

36. Wood RE, Lacey SR, Azizkhan RG. Endoscopic management of large, postresection bronchopleural fistulae with methacrylate adhesive (Super Glue). J Pediatr Surg 1992; 27:201-02.
37. Wood RE. Pitfalls in the use of flexible bronchoscope in pediatric patients. Chest 1990; 97: 199-203.
38. Castro M, Midthun DE, Edell ES, et al. Flexible bronchoscopic removal of foreign bodies from pediatric airways. J Bronchol1994;1:92-98.
39. Sarkar M, Nandoskar M. The Role of 10% Xylocaine Spray for Bronchoscopy in Paediatric Patient for Removal of Foreign Body. Bombay Hosp J. www. bombayhospital. com.
40. Becker HD. Stenting of the central airways. J Bronchol 1995;2:98-106.
41. Bolliger CT. Airway stents. Semin Respir Crit Care Med 1997;18:563-70.
42. Dasgupta A, Heights C, Dolmatch BL, et al. Self-expandable metallic airway stent insertion employing flexible bronchoscopy:preliminary outcome. Chest 1998; 114:106-09.
43. Dumon JF. A dedicated tracheobronchial stent. Chest 1990;97:328-32.
44. Freitag L. Tracheobronchial stents. In: Bolliger CT, Mathur PN (Eds): Interventional Bronchoscopy (vol 30). Basel, Switzerland:Karger, 2000;171-86.
45. Freitag L, Eicker K, Donovan TJ, et al. Mechanical properties of airway stents. J Bronchol 1995; 2:270-78.
46. Montgomery WW. T-tube tracheal stent. Arch Otolaryngol 1965;82:320-21.

Chapter 9

Complications of Fiberoptic Bronchoscopy

• Mritunjay Pao

Although flexible fiberoptic bronchoscopy is usually a safe and a well tolerated procedure, like all invasive procedures it is also associated with complications related to the procedure The risk of complications depends on the inherent risk factors in the patient such as the disease state, severity of illness, skill of the bronchoscopist and preparation of the patient for the procedure. All bronchoscopists should be well aware of the complications associated with flexible fiberoptic bronchoscopy and be prepared to prevent and manage them. At least one fatality has been reported in association of flexible fiberoptic bronchoscopy (FFB).[1] Complications can be grouped as physiological, mechanical and those related to anesthesia.[2]

Physiological Complications

These include hypoxia, hypercapnia, hypotension, laryngospasm, bronchospasm, transient fever, cardiac arrhythmias and aspiration.[2] All bronchoscopes produce some degree of airway obstruction which may result in hypoventilation, hypoxia and hypercapnia. The risk of complication is greater in smaller children. Inadequate sedation or local anesthesia may lead to vagal stimulation or catecholamine release, which may cause cardiac arrhythmias or result in bronchospasm or laryngospasm. During bronchoscopy in patients with reactive airway disease mechanical stimulation of the airway may produce severe bronchospasm. This usually reverts quickly with nebulized salbutamol. Tachycardia

may indicate impending hypoxemia and bradycardia is an indication for removal of the bronchoscope and the patient should be ambu bagged with 100 percent oxygen using a C-circuit to reverse the hypoxemia quickly.[3] Aspiration can be avoided by keeping the patient nil by mouth for six hours before the procedure and emptying the stomach through a large bore nasogastric tube. Physiologic complications can be reduced by adequate patient preparation, adequate anesthesia and proper bronchoscopic technique.

Hypoxia is the most common and greatest risk associated with flexible bronchoscopy. This may be a consequence of laryngospasm, bronchospasm or excessive coughing, partial or total obstruction of the airway by the bronchoscope and depression of the respiratory drive due to sedation. The major determinants of hypoxemia during bronchoscopy include increase in airway resistance, excessive sedation and disturbances in the ventilation perfusion relationship.[4] The incidence of desaturation can be reduced by the extensive use of oxygen supplementation.[5] The administration of oxygen may mask possible hypercapnia[6] and end-tidal carbon dioxide is useful in detecting it early and to initiate effective manual ventilation. Intravenous sedation with midazolam and/or the topical application of lidocaine to the upper airways may aggravate laryngomalacia[7] which may aggravate hypoventilation and hypoxia. Oxygen desaturation has been reported to be more

frequent in very young children than in older patients.[5,8,9]

Transient fever (peak body temperature >38.5°C) occurring 4-8 hours after bronchoscopy is most often seen after bronchoalveolar lavage and has been suggested to be caused by the BAL-induced release of cytokines (like tumor necrosis factor-α) from the alveolar cells.[10,11] Spread of infection is a very rare complication of FFB. A lung abscess was reported in one case in the series by Wood.[12]

Mechanical Complications

These result from direct impact of the bronchoscope on the airway structures resulting in pneumothorax, pneumomediastinum, perforation, transient stridor due to subglottic edema and bleeding.[2] These complications increase when procedures like transbronchial biopsies and foreign body extraction are performed. Proper technique and avoiding excessive pressures while introducing the bronchoscope will prevent trauma. During nasal insertion if there is difficulty in passing the scope through one nostril, insertion should be attempted through the opposite nostril. Very rarely the scope may have to be inserted through the oral cavity.[4] Use of a gag is necessary during oral insertion. Minor bleeding usually stops spontaneously or after application of Adrenaline (1:10,000 dilution) through the bronchoscope. Bleeding is usually transient and more commonly associated with transbronchial

biopsies. Epistaxis is more common after nasal insertion and use of excessive force should be avoided while inserting the bronchoscope. Transient stridor is usually mild and usually resolves within 24 hours.

Complications Associated with Sedation

Inadequate use of topical anesthesia may cause laryngospasm or bronchospasm.[3] In our center commonly used sedatives include intravenous ketamine and midazolam. Midazolam usually causes respiratory depression which can be reversed by flumazenil. Ketamine is associated with excessive secretions requiring frequent suctioning (Atropine is usually not required) and emergence phenomenon (excessive irritability) which is minimized if midazolam is used concurrently. Fentanyl is commonly associated with chest wall rigidity and respiratory depression which can be reversed with the use of Naloxone. Some centers prefer general anesthesia.

The severity of complications of flexible bronchoscopy can be grouped as minor or major.[5,16] Minor complications are events that do not affect or preclude completion of the procedure. These include epistaxis, moderate and transient episodes of desaturation (decrease in oxygen saturation to <90% and desaturation episodes lasting <60 seconds), transient laryngospasm, moderate coughing or nausea. Major complications are events that affect the procedure and require intervention, termination of the procedure

in particular. These include pneumothorax, decrease in oxygen saturation to <90 percent either isolated or associated with laryngospasm, bronchospasm, and coughing.

In a prospective study involving 1328 procedures, designed to evaluate the adverse effects of flexible bronchoscopy in children. De Blic et al[5] reported minor complications in 5 percent of cases and major complications in <2 percent. In their study a total 92.8 percent of the procedures were performed in conscious patients under sedation and 7.2 percent under deep sedation. Supplementary oxygen was provided in 80 percent of cases via endoscopic face mask or nasal prongs. At least one complication was recorded in 6.9 percent cases. Minor complications (5.2%) included moderate and transient episodes of desaturation, isolated excessive coughing, excessive nausea reflex with coughing , transient laryngospasm and epistaxis. Major complications included oxygen desaturation to <90 percent, either isolated or associated with laryngospasm, coughing, bronchospasm, and pneumothorax. Major complications involving oxygen desaturation were associated with age <2 years and laryngotracheal abnormalities. The overall frequency of complications was similar in conscious (6.7%) but sedated patients and patients under deep (7.3%) sedation. However, the frequency of transient desaturation was significantly higher in children undergoing flexible bronchoscopy under deep sedation.

Transient fever (body temperature >38.5°C) after bronchoalveolar lavage was observed in 52 of 277 cases (18.8%).

In another large study involving 2836 children Nussbaum[13] reported that there were no fatalities. Twenty one (0.8%) children experienced transient, although significant (65-85%) oxygen desaturations, of these 5 required emergency endotracheal intubations. The other 16 patients improved with oxygen supplementation and prompt withdrawal of the bronchoscope from the airway. Tachycardia or bradycadia were transient. Two of the 5 intubated patients had apnea before the procedure due to fentanyl induced chest wall rigidity or respiratory depressant effects of midazolam and fentanyl. The other three had pulmonary infiltrates with ateclactasis, which required suctioning for BAL, and experienced severe oxygen desaturations during the procedure. All of their patients recovered uneventfully. The other complications seen were mild nasopharyngeal bleed, stridor, intrabronchial bleed after biopsy, laryngospasm and bronchospasm, all of which were transient and the patients recovered uneventfully.

Prevention of Complications

Flexible bronchospcopy is now widely used in pediatrics for a wide range of indications mostly in children with chronic diseases and many of them have precarious respiratory status. Therefore, it is necessary

to maintain a high level of safety with an aim to minimize complications associated with it, especially in anxious and combative children.

Adequate sedation with maintenance of spontaneous respiration facilitates successful completion of the procedure with minimal coughing, laryngospasm and oxygen desaturation. A local anesthetic spray like Lignocaine on the larynx before the procedure will minimize laryngospasm. In children with bronchial asthma and reactive airway disease adequate pretreatment with nebulized Salbutamol (0.15 mg/kg) and a dose of steroid will minimize the risk of bronchospasm. Special precautions should be taken for children <2 years and those with known or suspected laryngotracheal abnormalities because these two groups of children have the highest risk of oxygen desaturation.[5]

Use of Laryngeal Mask Airway

The use of laryngeal mask airway as an alternative to endotracheal intubation has been reported to be associated with decreased incidence of complications associated with flexible bronchoscopy. It is especially useful in cases of difficult airways and abnormal anatomy where endotracheal intubation may be difficult. It also prevents the risk of trauma associated with endotracheal intubation. Because of its size the LMA can accommodate a larger bronchoscope than the endotracheal tube thus allowing a bronchoscope with

a suction channel to be used facilitating adequate suctioning.[14] Secondly, the resistance to gas flow is fifty percent less than a conventional endotracheal tube.[15] Even the smallest LMA (#1) allows passage of a 3.5 mm bronchoscope with a 1.2 mm suction channel.

Whenever possible a bronchoscope of the smallest diameter should be used. Use of a 2.8 mm flexible bronchoscope equipped with a 1.2 mm suction channel has been reported to decrease the occluded area by 40 percent.[8] Oxygen supplementation via a mask or nasal prongs reduces the risk of oxygen desaturation. In patients without endotracheal intubation, use of a endoscopic face mask makes it possible to deliver 50 percent inspiratory oxygen fraction regardless of the sedation used.[5] Bronchoscopy with bronchoalveolar lavage and endobroncial biopsy can be done safely even in children with chronic respiratory symptoms and difficult asthma.[16,17]

Minimum standards for monitoring during bronchoscopy should include routine monitoring of ECG, blood pressure, end tidal carbon dioxide and pulse oximetry, both during and after the procedure. All units undertaking flexible bronchoscopy in children should have a dedicated area for the procedure and such units should develop their own individualized protocols for sedation and the procedure and follow it rigorously. Sedation and monitoring of the child should be done by a second person skilled in pediatric resuscitation and intubation. In hands of skilled professionals flexible fiberoptic bronchoscopy is a safe procedure.

REFERENCES

1. Wagener J S. Fatality following fiberopotic bronchoscopy in a two-year-old child. Pediatr Pulmonol, 1999;3:197-99.
2. Wood RE. Bronchoscopy. In Chernick V, Boat TF. (Eds): Disorders of the Respiratory Tract of Children 6th ed. WB Saunders (Phil); 1998:129-42.
3. Chhajed P, Cooper P. Pediatric flexible bronchoscopy. Indian Pediatr 2001;38:1382-92.
4. Green CG, Eisenberg J, Leong A, Nathanson I, Schnapf Bm, Wood RE. Flexible endoscopy of the Pediatric airway. Am Rev Respir Dis.1992;145:233-35.
5. J de Blic, Marchac V, Scheinmann P. Complications of flexible bronchoscopy in children: prospective study of 1,328 procedures. Eur Respir J 2002;20:1271-76.
6. Erb T, Hammer J, Rutishauser M, Frei FJ. Fibreoptic bronchoscopy in sedated infants facilitated by an airway endoscopy mask. Paediatr Anaesth 1999;9:47-52.
7. Nielson DW, Ku PL, Egger M. Topical lidocaine exaggerates laryngomalacia during flexible bronchoscopy. Am J Respir Crit Care Med 2000;161:147-51.
8. Schnapf B. Oxygen desaturation during fiberoptic bronchoscopy in pediatric patients. Chest 1991;99:591-94.
9. Gibson NA, Coutts JA, Paton JY. Flexible bronchoscopy under 10 kg. Respir Med 1994;88:131-34.
10. Standiford TJ, Kunkel SL, Strieter RM. Elevated serum levels of tumor necrosis factor-alpha after bronchoscopy and bronchoalveolar lavage. Chest 1991;99:1529-30.
11. Krause A, Hohberg B, Heine F, John M, Bursmester GR, Witt C. Cytokines derived from alveolar macrophages induce fever after bronchoscopy and bronchoalveolar lavage. Am J Respir Crit Care Med 1997;155:1793-97.
12. Wood RE. Spelunking the pediatric airways: explorations with the flexible fiberoptic bronchoscope. Pediatr Clin North Am 1984;31:785-99.
13. Nussbaum E. Pediatric fibreoptic bronchoscopy: clinical experience with 2836 bronchoscopies. Ped Crit Care Med.2002: 3:171-76.

14. Smyth AR, Bowbay AR, Heaf LJ, et al. The Laryngeal mask airway in pediatric fibreoptic bronchoscopy. Arch Dis Child 1996;75:344-45.
15. Brimacombe J, Dunbar-Reid K. The effect of introducing fibreoptic bronchoscope on gas flow in laryngeal masks and tracheal tubes. Anesthesia 1996;51:923-28.
16. Payne D, McKenzie SA, Stacey S, Misra D, Haxby E, Bush A. Safety and ethics of bronchoscopy and endobronchial biopsy in difficult asthma. Arch Dis Child 2001; 84:423-26.
17. Salva P S, Theroux C, Scwartz D. Safety of endobronchial biopsy in 170 children with chronic respiratory symptoms. Thorax 2003;58:1058-60.

Chapter 10

Rigid Bronchoscopy

• Meera Luthra

Rigid bronchoscopy is a commonly required procedure in children for removal of foreign bodies or removal or excision of lesions in the airway such as granulomas, hemangiomas or other similar lesions amenable to laser or surgical excision.The development of small diameter flexible scopes allow medical specialists to access the airway in the conscious sedated child and in the event foreign bodies are visualized these may then be removed using a rigid scope. There will be several instances where the history of foreign body aspiration is classical and a rigid bronchoscopy is the first procedure done for diagnostic or therapeutic intervention. A history taken first hand by the endoscopist is mandatory. Often, in a case of foreign body in the airways, the classical history is that of a child between 1 to 2 years who was eating a peanut or some hard object and suddenly starts to cough. The child is often scolded by an elder at home and chokes on the foreign body. The symptoms vary from mild cough to acute respiratory distress and cyanosis. The age is classically between 1-2 years although it is possible in an infant and an older child. One of our patients was a twelve-year-old who had broken a tooth and thought he had swallowed it, until a plain X-ray 3 months later showed this tooth in the right bronchus. It was subsequently removed bronchoscopically at the second attempt.

INSTRUMENTS

The integrated bronchoscopes that we currently use vary from size 2.5 which are 20 cm length to size 5 which

are 30 cm long. Rarely, the older children who are bigger require still bigger and longer scopes. Each of these scopes has a suction channel at an angle to the main channel for inserting a flexible foreign body forceps. One horizontal link is attached to a prism, which is connected to a light cable which is attached to a cold light source. In scopes size 3.5 or more a telescope is inserted from the main channel with or without an optical forceps. A rigid suction tube can be inserted from the main channel through a perforated rubber stopper. The second horizontal limit is connected to a standard anesthesia circuit through which the patient is ventilated and anesthetized. Even with size 2.5 bronchoscope a 0° telescope may be used but only with flexible forceps. Alternately, light may be transmitted through the prism and the foreign body removed without magnification through the main channel. A sliding connector is used for this purpose over the main channel to prevent leak of gases. The final improvement in vision came with the advent of the camera which is fixed on the telescope and the bronchoscopy can be visualized online on a monitor. This adds to the safety and accuracy of the procedure wherein the anesthetist and other members of the operating team are able to see what is happening in the airway instead of constantly peering over the surgeon's shoulder. The other bronchoscopes are different lengths for 20 cm, 26 cm and 30 cm scopes with single action and double action jaws (Figs 10.1 to 10.4).

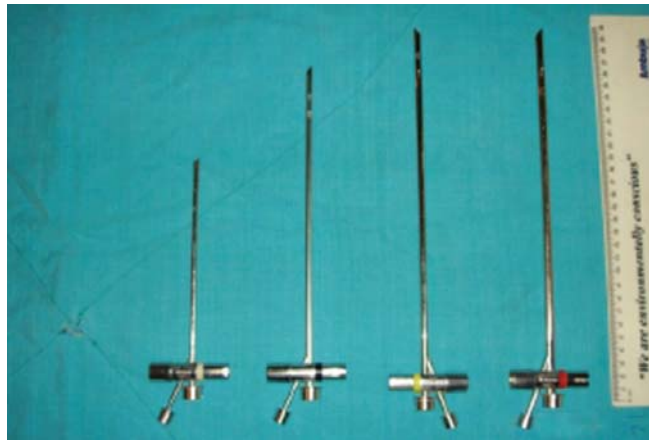


Fig. 10.1: Various sizes of rigid bronchoscopes

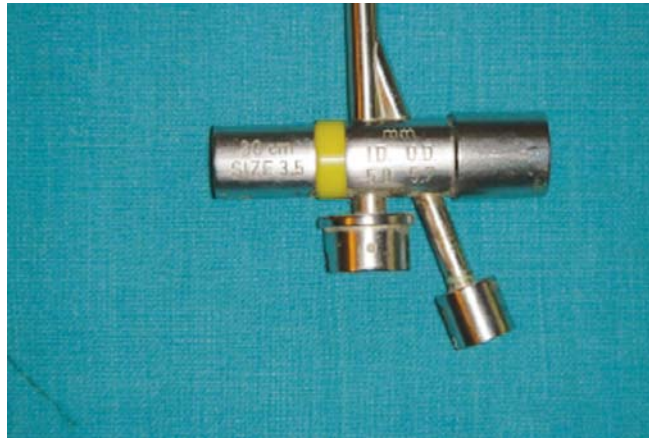


Fig. 10.2: Close view of proximal end of bronchoscope

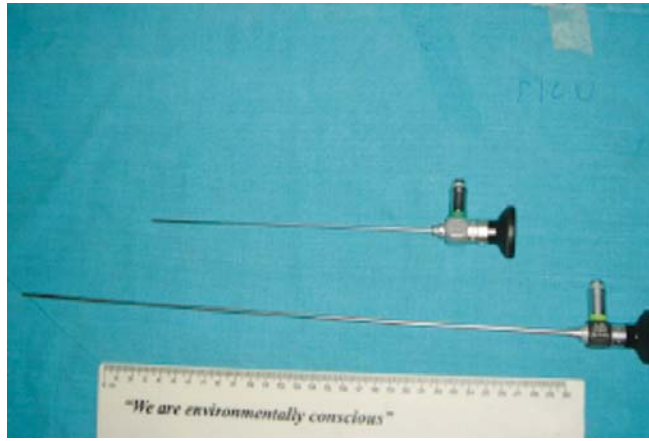


Fig. 10.3: Telescope

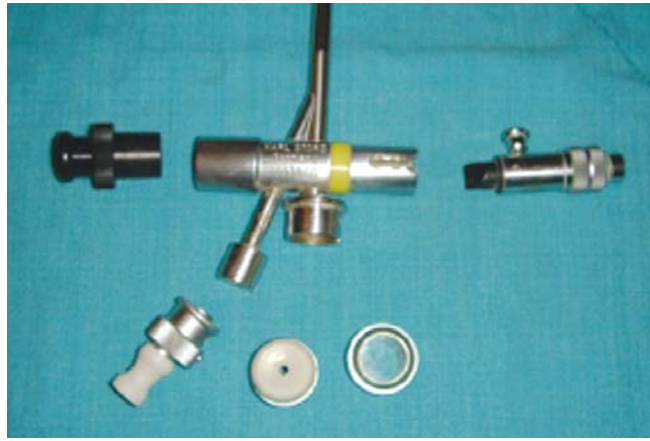


Fig. 10.4: Accessories for rigid bronchoscopy

Foreign body forceps come in various sizes and shapes. There is one which is flexible and passable through the suction channel (3F size). The shape is suitable for peanut, round foreign body and sharp foreign body. However, inspite of different shapes, there are still foreign bodies that will be not be extractable by the forceps. The bulb of a fogarty balloon distal to the FB with the balloon inflated is used to extract the difficult FB.

Some FB such as a screw with the head distally placed or an open safety pin or a ball bearing are sometimes best removed by a thoracotomy and bronchotomy rather than risk tearing the bronchus and trachea. Very rarely, a long-standing FB may necessitate a segmental or lobar resection for an impacted bronchial FB.

Symptoms of foreign body aspiration vary from mild cough to being diagnosed as bronchial asthma and acute respiratory distress. Examination may reveal decreased breath sounds to hyperresonant breath sounds on the side of the FB. Sometimes, the patient becomes cyanosed at home or in the emergency department and may even die from the inhaled FB. Pnuemothorax in a child seen by the author who had a right bronchus FB-obstructing the right main stem bronchus (a chick pea) that was causing emphysema due to ball valve mechanism. A CT scan done to delineate the right bronchus picked up the FB only because of the high clinical suspicion.

PROCEDURE

Rigid bronchoscopy is done under general anesthesia with or without a muscle relaxant. It may need to be done as an emergency or an emergency procedure the next morning provided the patient is kept under close observation in a pediatric intensive care unit (PICU)and at any worsening of symptoms the patient is taken up as an emergency. The vocal cords are sprayed by a local anesthetic so that when the endoscope is introduced often with the help of a laryngoscope to introduce it under vision there is no laryngospasm. Today, with sensitive oxygen saturation (SpO_2) monitors, no patient should have hypoxia and bradycardia before an anesthetist alerts the surgeon that the airway is being compromised. Earlier, when the oxygen monitors were not freely available, cardiac monitors were used to monitor the pulse and even before that the anesthetist would monitor the pulse by feeling the radial pulse. Even today, in addition to monitors it is a good idea to have an anesthetist feel the pulse. Oxygen therapy via the gas port should be used during the bronchscopy. Jet ventilation can also be used in a ventilating bronchoscope while the procedure is being performed. A vigilant monitoring of chest rise and pulse oximeter saturation is done constantly.

Rigid bronchoscopy is the one procedure where there has to be a very good understanding between the surgeon and the anesthetist. Ideally, there should be two anesthetists and two surgeons who are familiar with the procedure as well as the instruments. The

classical patient is between 1-2 years and the foreign body is lodged in the right bronchus, as this is more in continuation with the trachea. Beware of the foreign body in the left bronchus, as they are notorious for slipping into the right bronchus after coming into the trachea. FB in the trachea or those that get stuck at the larynx either due to their size or placement transversely or due to a laryngospasm may warrant an emergency tracheostomy. One such patient had aspirated a stone and while removing it the FB got stuck just below the cords. An emergency tracheostomy saved the child's life. Twenty-four hours later, the FB was removed proximal to the tracheostomy. Peanuts often break into pieces once they have been there for more than 24 hours and cause infection and inflammation and even pus may be seen on certain occasions. Bones or metal pins or needles may be difficult to remove.

Course in hospital in a patient with an inhaled FB may be so smooth that the patient may go home within 48 hours or with a difficult FB the patient may require more than one attempt at removing the residual FB. At other times, the patient requires mechanical ventilation. The child may cough out pieces of peanut once the main piece has been removed. Injury may also occur to the trachea or bronchus (various types of foreign bodies are shown in Figures 10.5 to 10.10).

Proper instruments are very important and before a rigid bronchoscopy is undertaken the surgeon/trained nurse must personally check that each and every thing

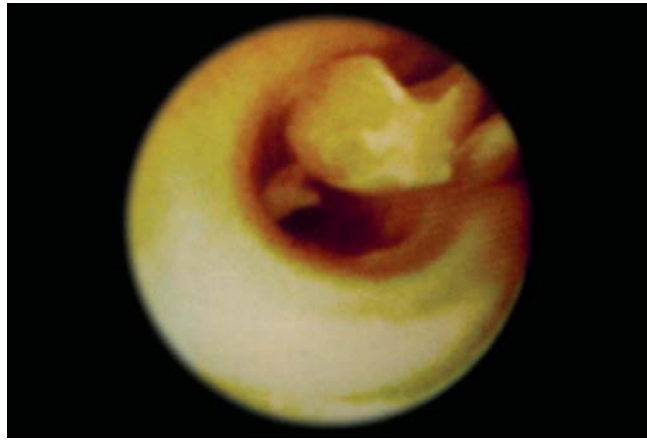


Fig. 10.5: Peanut in the airway

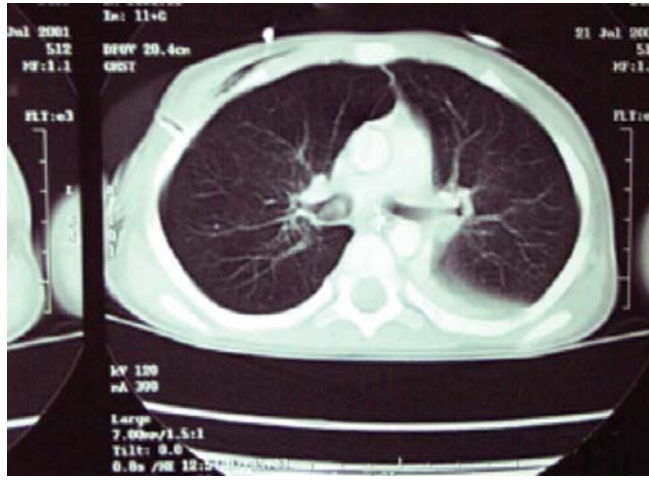


Fig. 10.6: CT scan showing foreign body in right mainstem bronchus

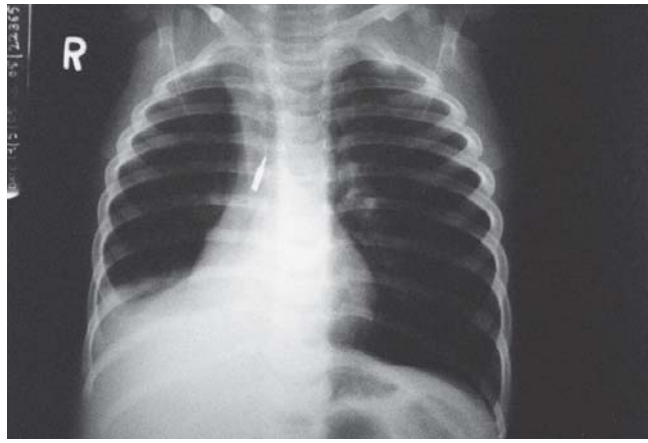


Fig. 10.7: Chest radiograph showing small pen tip in right mainstem bronchus

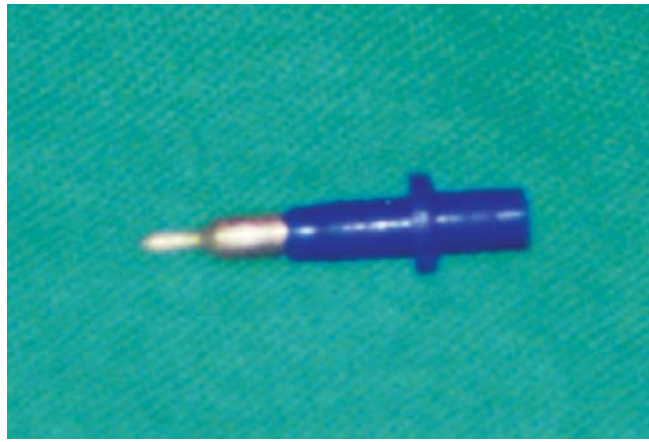


Fig. 10.8: Removed pen tip after bronchoscopic removal

Fig 10.9: Various particulate foreign bodies

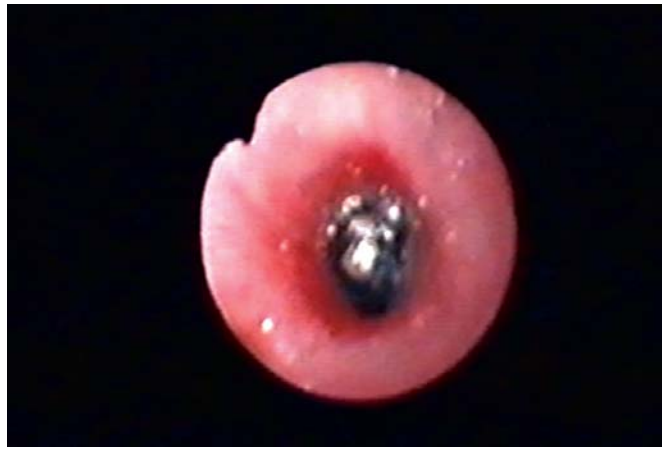


Fig. 10.10: Blackpepper aspirated into bronchus

is in working order including the light cable. Finally, rigid bronchoscopy has a certain morbidity such as pneumothorax, airway injury, hypoxemia and bleeding and very rarely, a real risk of mortality though generally, it is a safe procedure in skilled hands. A written consent must be taken by the surgeon explaining the purpose of this procedure and the possible complications including respiratory arrest. With the complete range of instruments, camera and television monitor, cardiac and oxygen monitors and a competent surgeon and an equally competent anesthetist the risk of rigid bronchoscopy must be minimized and the majority of patients should have an uneventful recovery.

Postoperatively, strict vigil must be maintained and the risk of acute respiratory distress and death due to edema of the vocal cords must not be undermined. Whenever multiple attempts have been made at removing the foreign body there is a role of steroids and nebulization to reduce the risk of acute respiratory arrest. Finally, bronchoscopy is a life saving procedure which is risky. We must not undermine the importance of the preoperative, intraoperative and postoperative management.

Chapter 11

Indian Experience with Pediatric Flexible Fiberoptic Bronchoscopy

• Krishan Chugh

In some of the centers in USA pediatric flexible fiberoptic bronchoscopy (FFB) started more than 2 decades back. By 1987 Reddy and Vauthy from Ohio had performed the procedure in over 4,000 cases. Wood had performed FFB in over 3,000 cases by 1992. Similarly, Fan has been working with the flexible bronchoscope since at least 1981 and Deblic reported therapeutic applications of FFB in pediatrics as early as 1984. Recently Nussbaum has published his 20 years experience with pediatric fiberoptic bronchoscopy. In India too FFB was started by Somu and colleagues at Institute of Child Health, Chennai quite early. They reported their experience of 630 cases from January 1989 to August 1995. However, only 12.3 percent of their patients were less than 4 years old and the youngest was 50 days. In our institution almost half (47.2%) of the children were less than one year age (Table 11.1). In the Chennai study almost 30 percent of the children had bronchiectasis, a condition that we see very seldom in young children at our center. In the Chennai study no comment has been made about the dynamic problems of the airways. We encountered significant number of cases of laryngomalacia, bronchomalcia and tracheomalacia (Tables 11.2 to 11.4). Nussbaum's series had 19 percent of subjects below 12 months age and the pathology diagnosed had a similar spectrum as ours.

Table 11.1 Age and sex distribution of FFB cases (Jul 1993 to Jan 1996)

Age	*No. of Procedures*	*Percentage*
<1 months	284	8.8%
1-3 months	520	16.1%
3-12 months	721	22.3%
1-5 years	1013	31.4%
>5-10 years	382	11.8%
10 years +	306	9.5 %
Total	3226	100% M-56% F-44%

Table 11.2 Primary suspected pathology in upper airways (n=1096)

• Laryngomalacia	414
• Post-intubation supraglottic edema/injury	203
• Subglottic edema/congestion/stenosis	254
• Normal Larynx	34
• Post-tracheostomy upper airway evaluation	162
• Unilateral vocal cord palsy	7
• Bilateral vocal cord palsy	1
• Choanal stenosis/atresia	7
• Vocal cord dysfunction syndrome	2
• Submucosal retention cyst	2
• Subglottic ring	4
• Laryngeal web	2
• Thermal injury	2
• Foreign body at larynx	1
• Subglottic hemangioma	1
• Epiglottitis	0
Total	1096

Table 11.3 Primary suspected pathology in trachea (n=611)

• Post-intubation tracheal granulation	136
• Foreign body in trachea	47
• Compression of trachea from outside	
-Lymph nodes	109
-Cardiac chambers	41
-Vascular ring	03
-Mediastinal mass/cyst	37
• Tracheomalacia	123
• Tracheal stenosis	
-Congenital	06
-Acquired	28
• Tubercular granulations in trachea	54
• Candidiasis of trachea	09
• Bacterial tracheitis	26
• Probable viral tracheitis	22
• Tracheomegaly	04
• Tracheoesophageal fistula (TOF)	14
• Post-TOF surgery tracheal wall pathology	11
• Tracheal injury (Tear)	
-Post-surgical	1
-Post-foreign body removal	1
• Normal trachea	22

Table 11.4 Suspected primary pathology in bronchi/lungs (n=1436)

Diagnoses of lower airway	
• Inflammatory changes	723
Focal	429
Diffuse	294
• Mucopurulent plugs	206
• Foreign body	
Inert	280

Contd...

Contd...

Diagnoses of lower airway	
Localised granulation tissue/pus	96
Widespraed inflammation	29
With " sentinel sign"	16
• Bronchomalacia	54
• Outside compression of bronchus	37
• Tubercular granulation tissue	68
• Post-endotracheal suctioning trauma/ grannulations	20
• Agenesis of lobe/lung	09
• Post-traumatic bronchial obstruction	2
• Broncho-esophageal fistula	1
• Pulmonary hemosiderosis	6
• Lung abscess	16
• Bronchomegaly (Wilson syndrome)	1
• Bronchial stenosis	24
• Situs inversus	3
• Bronchopleural fistula	2
	1436

Evaluation of Upper Airways and Larynx

When the flexible scope is being passed through the nose and pharynx the bronchoscopist has an opportunity to examine these areas. Problems like choanal atreisa and choanal stenosis are detected and evaluated. However, the area of maximum interest to the pediatrician is usually the larynx, the supraglottic sturctures, the vocal cords and glottis and the subglottis. Care and patience during examination of laryngeal area along with video recording (for possible review later) greatly enhance the diagnostic value of FFB.

Laryngomalacia and paralysis of vocal cords are two most common abnormalities of the larynx besides laryngeal stenosis, congenital web etc. The movements of vocal cords with each respiration and during phonation should be observed carefully. Nussbaum detected 14 cases of vocal cord dysfunction in his series of 2,836 cases. Paralysis of vocal cords and scar tissue formation may interfere with the movements of the cords.

Laryngomalacia is well studied by the flexible scope. The size, shape and floppy nature of the arytenoids, epiglottis and the aryepiglottic folds can be assessed during spontaneous quiet breathing (in well-sedated child) and during crying/activity, etc. This is helpful in therapeutic decision-making. Not all cases of laryngomalacia are benign and mild. We have performed tracheostomy for this indication and have seen a death occur after the diagnosis was made but treatment refused by the parents in another child.

Evaluation of cases of croup before intubation, at the time of attempted extubation, at failed extubation, at time of deciding for tracheostomy and at the time of attempt at decannulation of tracheostomy has been advocated. Diagnosis of bacterial tracheitis by FFB can be very helpful in patients presenting with signs and symptoms of croup. Subglottic area is crucial in cases of pathology in laryngeal area, especially in post-intubation patients. Subglottic edema, congestion, mucosal injury, narrowing and granulation formation

are the common abnormalities encountered. Failure to or difficulty in negotiating this area during endotracheal intubation is an indication for bronchoscopic evaluation.

Evaluation of Tracheostomy

Once a tracheostomy tube has been inserted the child may require repeated bronchoscopic examinations of the larynx and lower structures to evaluate their present condition and possible readiness for decannulation. Granulation tissue at the stoma obstructing the trachea or in lower trachea may develop in such children. The anterior wall of the trachea at the site of stoma may move posteriorly, thereby narrowing the airway.

When the main pathology was in the larynx, say stridor, the bronchoscope is passed through the nose and supraglottic structures, vocal cords and the subglottic space evaluated. If these are assessed to be better and child ready for decannulation the scope should be passed further down (after removing the tracheostomy tube if it cannot be passed by its side). This way the lower airways are also examined.

Sometimes, the bronchoscope can be passed through the stoma by the side of the trachoeostomy tube without removing it. But, passing the scope through the tracheostomy tube may be easier, unless the tube size is too small.

If the examination of the uppermost part of trachea is not possible through the glottis because of severe narrowing there, the scope can be passed retrograde through the tracheostomy stoma and the extent of

subglottic narrowing evaluated. We have done this a few times and found it to be very useful.

Dynamics of Lower Airways

Collapse of the walls of trachea and/ or bronchi during expiration is a common acquired abnormality in infants and young children (tracheomalacia and bronchomalacia). Many children who continue to have 'wheeze' after extubation are suffering from these conditions. Naturally, they respond poorly to anti-asthma treatment. Occasionally, the condition may be severe enough to result in hypoxemia, sleep disturbances and apnea.

Foreign Body

When diagnosis of foreign body aspiration is certain, the child can be directly taken up for rigid bronchoscopy under general anesthesia. However, when situation is doubtful (dictum is "Always suspect a foreign body"), FFB is preferred. Similarly, occasionally a foreign body would be found in the airways when it was not the least suspected. Most large size foreign bodies are left alone on FFB and managed under general anesthesia by rigid bronchoscope. However, if the foreign body is in small pieces or located in a peripheral airway suction/ retrieval by basket or forceps through the flexible scope may be attempted.

Occasionally, the attempt to remove the foreign body by the rigid scope, even in the hands of most competent

and experienced bronchoscopist fails. A re-evaluation by FFB in such cases is helpful in planning the further course of management.

Sometimes, even after successful retrieval of the foreign body the clinical and radiological abnormalities do not improve well. This raises the possibility of incomplete removal. Re-evaluation by FFB may show this to be because of another piece of the foreign body or due to granulation, congestion and mucopurulent plugs.

Stridor: Clinical Condition

Stridor in children indicates anatomical or functional obstruction of the upper airways. Age of presentation, besides the other clinical features can be a useful diagnostic clue. For example, laryngomalacia is the commonest cause of stridor in early infancy. If the stridor is mild and classical features are present a clinical diagnosis of laryngomalacia can be made with reasonable certainty. However, if the obstruction is severe or atypical features are seen, a bronchoscopic evaluation of upper as well as lower airways should be done. Approximately, one-sixth of cases of laryngomalacia were associated with lower respiratory tract abnormalities in a large series.

Common Diagnostic Entities

- Congenital malformations of supraglottic, glottic, subglottic structures, trachea.

- Post-extubation edema/inflammation.
- Severe laryngomalacia, tracheomalacia.
- Tracheo-esophageal cleft.
- Foreign body.
- Vascular ring (e.g: double aortic arch).
- Infections, e.g: retropharyngeal abscess, diphtheria.
- Hemangioma.
- Laryngotracheal angioedema.

Bilateral Wheeze

Besides asthma, the following conditions can result in bilateral wheeze. When there is no response to anti-asthma treatment or there are other clues to the diagnosis (clinical or radiological), flexible bronchoscopy can be a useful tool in the evaluation of such a child.

Causes of Bilateral Wheeze in Children

- Tracheomalacia–primary or secondary.
- Bronchomalacia–primary or secondary.
- Stenosis
  - with complete tracheal rings;
  - without complete tracheal rings;
  - post-traumatic, e.g: post-intubation, post-burns.
- Vascular ring compressing the trachea.
- Foreign body at carina/in trachea.
- External compression of trachea:
  - enlarged lymph nodes;
  - cardiac chambers;
  - mediastinal cysts, masses.

- Endobronchial tuberculosis, both sides.
- Bronchiectasis.
- Neoplasms, hamartomas.
- Tracheal candidiasis.

Unilateral Wheeze

Persistent wheeze on one side or only in a localized area indicates a localized obstructive pathology. Such a patient is likely to benefit greatly by flexible bronchoscopy in diagnostic evaluation.

Unilateral/Localized Wheeze

- Foreign body.
- Endobronchial tuberculosis.
- Compression of bronchus from outside by
  - lymph nodes;
  - mediastinal mass;
  - vascular ring;
  - cardiac chambers.
- Bronchial stenosis
  - congenital;
  - acquired, e.g: post-intubation and vigorous tracheal suctioning.
- Congenital lobar emphysema.
- Endobronchial tumor.

FFB in Immunocompromized Child

Detection of opportunistic organisms in the BAL in immunocompromized host (e.g: HIV, anti-malignancy

treatment, congenital immunodeficiency disorders) is a very rewarding experience as it helps in planning the specific treatment. The child with unexplained radiological opacity may be an immediate beneficiary sometimes when an endobronchial tubercular lesion is detected or when *Mycobacterim tuberculosis* (M. TB) is identified on Ziehl-Neelsen staining or by fluorescent techniques. Cultures of M. TB and its sensitivity tests with antitubercular drugs is another step that is critical in decision-making regarding the specific anti-tubercular drugs to be used in such children.

However, commonest pulmonary infections even in the immunocompromized host are due to the usual pathogens like *Pneumococcus*, *Staplylococcus*, etc. When these organisms are cultured with high colony counts and associated with a strong polymorphonuclear response in BAL fluid the clinician can choose the suitable antimicrobial drugs, especially when resistant strains are the offending agents.

In a study conducted at Sir Ganga Ram Hospital, (GRH) New Delhi, 20 children (age range 10 mo-14 yrs) with neutropenia (absolute neutrophil count less than 1500/cumm) and pulmonary infilterates were subjected to BAL by FFB. All the cases had been on antibiotics without an adequate response. Four children showed *Pneumocystis carinii*, 4 showed fungus and 2 showed tuberculosis. Pyogenic pathogens were isolated in 8 patients. A number of other studies have shown BAL to be a useful procedure in immunocompromized children.

All the children tolerated the procedure well in GRH study except one who developed increased hypoxemia for a short while. Safety of the procedure, especially the low incidence of hemorrhage, in immunocompromized children has been emphasized in a recent review.

Role of FFB in Pulmonary Tuberculosis

Suspected pulmonary TB is ordinarily not an indication for FFB. However, when the response to treatment is not adequate, radiological opacities persist, atelectasis does not clear, FFB may prove useful. When differentiation from a non-responding pyogenic pneumonia or a foreign body aspiration is not clearly possible by other non-invasive investigations FFB should be done. Since children cannot produce sputum, confirming MDR tuberculosis is not easy. FFB provides an opportunity to examine the airways as well as obtain a sample for bacteriological examination.

Endobronchial tuberculosis lesions can be identified on FFB examination. Their brushings or bronchoalveolar lavage cytology may show the specific cells. In older children it may be possible to take a biopsy also. Further, the specific organism may also be demonstrated.

Gastric lavage fluid examination conducted early morning, on empty stomach has been used for identification and culture of the *Mycobacterium tuberculosis*. While some studies have found additional

advantage by doing BAL also, some other studies have shown gastric lavage to be superior. However, when suspicion for pulmonary tuberculosis is strong but gastric lavage fails to show acid-fast bacilli FFB and BAL should be performed. Overall, in childhood tuberculosis, the isolation rate for M. TB is not very high by any means.

FFB and BAL in Non-resolving Pneumonia in Immuno-competent Children

Persistent pneumonia which has not responded to the apparently correctly chosen antimicrobial treatment is not an uncommon situation in hospital practice. In the majority of such children there is no reason to believe that they have any immunodeficiency. There may not be enough evidence to label that pneumonia as tubercular either. In such cases after sufficient trial has been given or if the situation is deteriorating inspite of the well-chosen antimicrobials or if radiological/clinical features suggest the possibility of unusual/resistant organism FFB and BAL should be done.

In our experience FFB may help in diagnosis of an unexpected foreign body; compression of a bronchus, lung abscess missed on chest X-ray and computed tomography, etc. Further, BAL performed in these cases may yield a fungus, resistant bacteria (*Staphylococcus aureus* is not an uncommon pathogen), *Pneumocystis carinii,* etc. as the possible pathogen (unpublished data from GRH). Rock (1995) also found BAL to be useful

in selected patients of nonresolving pulmonary infiltrates in immuno-competent children.

Many of the organisms identified in BAL fluid are also the commensals of upper respiratory tract through which the bronchoscope inevitably passes and contamination invariably occurs. To increase the specificity of BAL fluid cultures in diagnosing common bacterial pneumonia the concept of quantitative BAL cultures was introduced on the lines of urine culture colony counts. Using such quantitative cultures cut off points of 10^4 or 10^5 colony forming units (cfu)/ml have been suggested in the literature. Our own studies have shown 10^4 cfu/ml to be a useful cut-off value between possible commensals and pathogens.

Aspiration Pneumonia

Children with suspected aspiration pneumonia may benefit from FFB. Tracheo-esophageal cleft, H-type tracheoesophageal fistula etc. can be diagnosed. Techniques for identifying the-type fistula using methylene blue dye have been described. Some children have frequent lower respiratory tract infections following repair of congenital tracheo-esophageal fistula (TOF) with a tracheal character cough and/or wheeze. FFB evaluation of such children may yield tracheomalacia in the repaired segment, stenosis or just irregular architecture of the mucosa in this segment. Rarely, there may be a recurrence of the fistula or an incomplete repair may be the cause for recurrent

aspiration pneumonia. Damage caused by repeated episodes of aspiration pneumonia can also be evaluated.

Atelectasis

Atelectasis of the whole lung, a lobe or a segment is a common condition encountered in the NICU, PICU and the postoperative wards. This is often due to mucus plugs or mucopurulent thick secretions or granulations caused by suction catheter/endotracheal tube trauma. Sucking out of the mucus plugs proves useful in a number of such children, especially when hydration, humidification, nebulization, vibrations and chest physiotherapy have failed. Removal of the mucus plug may have an effect akin to removing the cork out of a bottle, that is, opening a closed bronchus and allowing the relevant part of lung to expand immediately. However, the results are not as dramatic most of the times. Bar-Zohar and Sivan reported a success rate of 74 percent of treating lung atelectasis by FFB and lavage.

Bronchial stenosis, a mass lesion within the bronchus or compression of the airways from outside may be the cause of atelectasis. Some of these problems have not only been evaluated by FFB but even treated using laser.

Role of FFB in PICU

From July 1993 to Jan 1996, FFB was carried out 108 times in patients in the PICU at our institution. Majority of the patients were below 2 years age (69%), with the youngest child being 2 days old. Minimum weight of

the child undergoing bronchoscopy was 1.5 kg. Males predominated. Common indications for FFB were stridor (16%), suspected foreign body (23%), atelectasis (24%), non-resolving pulmonary infilterates (29%) and persistent or atypical wheeze (11%). In six cases, nasotracheal intubation was carried out with the aid of the bronchoscope.

Frequent findings included purulent material in airways, mucopurulent plugs, severe laryngomalacia, tracheomalacia, foreign body, post-intubation granulations and tracheobronchomalacia.

Bronchoalveolar lavage was performed in 68 (61%) procedures and proved useful in planning further treatment in all these cases.

FFB was helpful in evaluation airways in all patients. It helped in clearing the airways of blocking secretions or plugs in 32 (29%) procedures. In two cases foreign material (thin peel of groundnut in one case and forcibly fed 'meal' in another case) was sucked out and rigid bronchoscopy was avoided. In all other cases of foreign body removal was carried out under general anesthesia by rigid bronchoscopy in the operation theater.

Minor complications occurred in 11 percent patients, commonest being transient dip in oxygen saturation. No major complications were encountered.

Role of FFB in Ventilator Associated Pneumonias (VAP)

Children on the ventilator often develop new opacities in their lungs when on the ventilator, especially when

ventilation is prolonged. Identifying the causative organism of ventilator associated pneumonia and choosing the appropriate antibiotic can be crucial. Endotracheal suction, blind bronchial sampling (BBS), a 'blind' bronchoalveolar lavage and FFB assisted BAL are the techniques employed for obtaining the 'secretions' from the lower airways. In a study, we compared these four techniques in children with VAP. Analysis of secretions obtained by endotracheal suction was found to be as sensitive but less specific than BAL obtained by FFB.

FFB IN NEONATES

The first fiberoptic bronchoscope that was useful in neonates was the 3.5 mm Olympus bronchoscope with a 1.2 mm suction channel. Later, even smaller diameter scopes (upto 1.8 mm) with flexible tips have been developed and are being increasingly used in evaluation of pulmonary pathology in newborns. We have performed bronchoscopy with or without BAL in a fairly large number of newborns using 3.5 mm and 2.8 mm Olympus bronchoscopes. The smallest size baby was 900 grams preterm. Taking all the appropriate precautions we have not encountered any major complications, nor is the rate of minor complications any higher in this age group. Yes, the time for which the bronchoscope can be kept below the glottis in very small babies has to be limited and the bronchoscope withdrawn at the earliest indication of a significant

problem, like desaturation on pulse oximeter. Supplemental oxygen is essential in all cases.

Indications of bronchoscopy in newborns are discussed below and the yield of FFB in the common indications are summarized in Table 11.5.

Table 11.5 **Diagnostic yield from flexible bronchoscopic procedures in the neonatal period based on indications for bronchoscopy**

Indications
• Stridor
• Acute respiratory distress
• Congenital anomalies
• Bleeding
• Wheezing
• Atelectasis/Emphysema
• Failed extubation
• Post-extubation problems
• Acute life-threatening episodes
• H-type TOF

Urgent Indications

1. Suspected airway obstruction in intubated neonate. The obstruction may be in the tube, at its lower end or even beyond. Usually, the cause is thick secretions/mucus plugs. These can be sucked out, thereby obviating the need for tube removal and reintubation.
2. Suspected dislodgement of the endotracheal tube is also best handled with the help of FFB. Infact, it has been the experience of many at the highly specialized neonatal units that confirmation of the position of

lower end of the endotracheal tube by FFB takes less than 60 seconds while a portable X-ray film takes much longer. This time period may be crucial for a newborn with acute severe deterioration. Indeed, Vigneswarm and Whitefield showed that bronchoscopy resulted in lesser desaturation than radiography and was also more accurate.

3. Evidence of airway obstruction after extubation is a common phenomenon. Quickly performed FFB can detect problems like laryngeal edema, vocal cord paralysis, prolapsing laryngeal structures, mucus plugging or simply posteriorly falling tongue. Fan at el in 73 consecutive post-extubation laryngeal evaluations found a 44 percent incidence of moderate or greater laryngeal injury. Fan et al and Sherman et al studied the risk factors for post-intubation subglottic stenosis. They suggest that stridor after extubation is a strong indication for bronchoscopy.
4. Vauthy and Reddy have pioneered the technique of intubating newborns using the flexible bronchoscope in difficult cases, e.g. hypoplastic mandible or maxilla, hydrocephalus or other malformations. Such intubations being nasotracheal are more useful. With experience this type of intubation can be done in a very short time.

Elective Indications

1. Determination of position of distal tip of an intubated infant has been shown to be reliably

confirmed by FFB. The time taken by Dietrich et al was 40 seconds compared to 30 minutes for X-ray.
2. Stridor or other signs of airway obstruction.
3. Recurrent atelectasis associated with intubation or following extubation to determine if there are tracheal abnormalities, e.g. tracheomalacia, tracheobronchomalacia .
4. Persistent localized emphysema.
5. Focal wheezing.
6. Wheezing not responding to bronchodilators.

Unusual Indications

1. Severe unilateral pulmonary interstitial emphysema.
2. Persistent unilateral airleaks.

Special Precautions in Preterms and Very Low Birth Weight (VLBW) Newborns

1. Avoid disturbing the newborn too much. Perform the procedure in NICU itself.
2. Oxygenate well throughout the procedure.
3. When already on ventilator increase FiO_2 to 1(100 percent).
4. Suction very gently and for minimum duration.
5. Use sedation/analgesia carefully.
6. Always use adequate local anesthesia.
7. Use smallest size bronchoscope that will serve the purpose. For most diagnostic work 2.2 mm ultrathin bronchoscope is preferred.
8. Interrupt the procedure as soon as significant problems like desaturation are noticed.

9. Perform the procedure in blocks keeping the bronchoscope below the larynx for a maximum of 30-40 seconds in one block.

Role of FFB in NICU

We have performed this procedure in a large number of NICU patients, sometimes at the bedside and at other times by shifting them to the bronchoscopy suite.

Age of neonates undergoing the procedure ranged between 1 and 78 days and the weight between 0.9 and 3.6 kg. Unexplained severe stridor, clinical evidence of lower airway obstruction, post-intubation/ventilation evaluation of airway, unexplained and persistent pulmonary opacities and atelectasis were the common indications. Evaluation of the airways for a suspected congenital anomaly is the most frequent indication in the early neonatal period.

Laryngomalacia severely obstructing the airways, tracheobronchomalacia, purulent material in lower airways, mucopurulent plugs, post-intubation/endotracheal suctioning granulations and unilateral choanal atresia were the endoscopic findings observed.

FFB with LMA

Laryngeal mask airway (LMA) of pediatric and neonatal sizes have now become available and are proving to be a useful adjunct in FFB. When the size of the endotracheal tube being used for an infant is less than 4 mm, it is not safe to pass a 2.8 mm bronchoscope

through it. In such situations, the endotracheal tube can be removed temporarily and replaced by a LMA. The bronchoscope can then be passed through the LMA. When the LMA is properly positioned, entry into the trachea is easily achieved. However, there is some limitation in evaluating the supraglottic structures when the scope is passed through a LMA. We have been very satisfied with LMA in the cases that we have used it. Nussbaum has also found LMA as a good alternative.

COMPLICATIONS (SEE CHAPTER 9)

FFB is a safe procedure even in the very sick, ventilator dependent children with major complications being uncommon and deaths rare (one death having been reported in 1987 by Wagener). Complications in 3 of the series are listed in Table 11.6.

Transient dip in arterial oxygen saturation, mild nasal bleed, transient hemoptysis, transient stridor, increased cough for a short while, over-sedation are some of the relatively common complications encountered. All the possible complications are listed in Table 11.7. It is important to anticipate problems, monitor the patient closely and take adequate precautions to minimize complications.

Recently, Bar-Zohar and Sivan have reported their experience with FFB in severely sick children in the PICU. In 155 procedures, no procedure-related death was encountered. Nor did they encounter any significant nasal/airway trauma, stridor, hemoptysis,

Table 11.6 Complications of FFB

	Wood (N = 1095)	*GRH* (n=3226)	*Reddy and Vauthy* (n=over4000)
Major			
Pneumothorax	2	0	6
Lung abscess	1	0	0
Laryngospasm	1	8	0
Massive hemorrhage		0	
Prolonged hypoxemia		16	
Arrhythmias	nil	1	nil
Minor			
Minimal nasal bleeding	8	28	5
Mild hemoptysis	4		
Increased cough for upto 1-2 hrs		47	
Transient stridor	2	29	1
Transient O_2 desaturation		46	
Over-sedation/anesthetic Complication	5	16	
Transient bradycardia	13	34	several

Table 11.7 Possible complications (all of them are uncommon)

Physiological	Hypoxia, Hypercapina, Arrhythmias, Laryngospasm, Bronchospasm.
Bacteriological	Transient fever, iatrogenic infection (if standard sterilization techniques not followed), Bacterial endocarditis in congenital heart disease patient, cross infection. Bronchoscopist and assistants exposed to patient's infection.
Mechanical	Pneumothorax, Hemoptysis, Lpistaxis,
Mucosal	laryngeal, trauma, edema, Subglottic edema.
Anesthetic complications	Oversedation, apnea.

pneumothorax, septicemia or cardiac arrhythmias. There was no significant reduction in PaO_2/FiO_2 ratio or deleterious effect on blood pH or $PaCO_2$.

Risk/Benefit Ratio

The risks involved are minimal except in critically ill child whose hemodynamics are unstable. To keep the risks low oxygenation is continued throughout the procedure. If still the child tends to desaturate the bronchoscope is removed immediately and reinserted again after the child stabilizes.

Care at minor details during the procedure ensures that the mucosa of the nostril, pharynx and lower airways are traumatized the least. Keeping a complete control over the angle of the tip of the bronchoscope and avoiding suctioning when the scope is against the wall is further helpful. Another precaution to minimize suction trauma is to keep the negative suction pressure in the recommended range. Similar precautions are necessary during BAL. Complications encountered during BAL by some workers are summarized in Table 11.6.

When inserting the scope into glottis a careful control over the tip of the scope and adequate local anesthesia of the area allows the skilled bronchoscopist to maneuver the scope into the trachea smoothly. This is helpful in avoiding post-bronchoscopy stridor/laryngeal spasm.

The benefits that will accrue to the patient by bronchoscopy should be evaluated carefully before the procedure is undertaken. Since FFB in skilled hands is safe and tolerated well most experts believe that it is an underused procedure and should be undertaken in any puzzling/difficult pulmonary condition.

Future of Pediatric FFB

Over the past 2 decades applications of pediatric FFB have widened greatly. More and more specialists, pulmonologists, neonatologists, anesthetists, ENT sugreons, cardiothoracic surgeons and pediatric surgeons have acquired the skills and the equipment to use this instrument for the benefit of their patients. As subspecialities advance and PICUs and NICUs reach higher levels of sophistication in the developing countries FFB will be done more commonly here in this part of the world too.

Newer applications of FFB in both diagnosis as well as in therapy are being explored. The BAL fluid can be analyzed by the sensitive techniques of polymerase chain reaction (PCR) and ELISA to detect organisms like mycobacteria, pneumocystis, CMV, HIV etc. Delivery of drugs to the targeted parts of lung and airways can be achieved by FFB, especially if the 'drug' cannot be well nebulized. Gene therapy for cystic fibrosis may be possible soon and FFB may be one method by which the gene can be delivered to the respiratory epithelium.

A study has described a method of quantitatively assessing the degree of airway collapse in infants and children with tracheobronchomalacia. A computer-assisted method is described besides the manual method. This combination of FFB with the computers's help may prove synergistic in future.

FURTHER READING

1. Budhiraja V. Evaluation of quantitative analysis of bronchoalveolar lavage specimens obtained by flexible fiberoptic bronchoscopy in pneumonia in children. Thesis for the Degree of Diplomate National Board (Pediatrics), National Board of Examinations, New Delhi, 1995.
2. Chugh K. Bronchoalvelar lavage by flexible bronchoscope without general anaethesia in non-resolving pneumonia starting in neonatal period. Abstracts of scientific papers. XIV Annual Convention of National Neonatology Forum India, 1994.
3. de Blic J, Delacourt C, Scheinmann P. Ultrathin flexible bronchoscopy in neonatal intensive care units. Arch Dis Child 1991;66:1383-85.
4. Finer NN. Flexible fiberoptic bronchoscopy. In: Spitzer AR (Ed): Intensive care of the fetus and neonate. Mosby, St. Louis, 1996;531-37.
5. Nussbaum E. Pediatric fiberoptic bronchoscopy: Clinical experience with 2,836 bronchoscopies. Ped Crit Care Med 2002:3:171-76.
6. Reddy RP, Vauthy PA, Saunder RA. Upper airway obstruction. Indian J Pediatr 1987;54:219-28.
7. Reddy RP, Vauthy PA. Flexible fiberoptic bronchoscopy. Indian J Pediatr 1987;54:237-43.
8. Satish P. To study the spectrum of microorganisms causing pulmonary infiltrates in patients with neutropenia by analysis of BAL fluid obtained by flexible fiberoptic bronchoscopy in children. Thesis for the degree of

Diplomate National Board (Pediatrics), National Board of Examinations, New Delhi, 1996.
9. Vauthy PA, Reddy R: Acute upper airway obstruction in infants and children. Evaluation by the fiberoptic bronchoscope. Ann Otol Rhinol Laryngol 1980;89:417-18.
10. Wood RE, Sherman JM. Pediatric flexible bronchoscopy. Ann Otol Rhinol Laryngol 1980;89:414-16.
11. Wood RE. Pediatric flexible bronchoscopy. A postgraduate course. School of Medicine, UNC, Chapel Hill, NC. 1992.
12. Wood RE. The diagnostic effectiveness of flexible bronchoscope in children. Pediatr Pulmonol 1985;1:188-92.

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