Chapter 121: Endoscopy of Tracheobronchial Tree and Esophagus

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Few diagnostic efforts provide more clinically useful information than direct inspection by the educated eye. The determination of what represents abnormal tissue and what further measures should be taken to confirm the impression or provide treatment largely depends on visual perception. The science of endoscopy has come to its present state of excellence through improved visual access into body cavities. Witness the profusion of papers on diagnosis and treatment of tracheobronchial and esophageal disease since the advent of the fiberscope and other fine optical devices.

This chapter reviews bronchoesophagology from the perspective of an otolaryngologist-head and neck surgeon who must often apply endoscopic techniques in the study of patients with a wide variety of diseases, injuries, and malformations. Otolaryngologists-head and neck surgeons must also recognize and often solicit the talents of colleagues in other specialities who have contributed much to our understanding and technology in this field.

The practice of nonsurgical endoscopists is frequently restricted to either the gastrointestinal tract or the respiratory system and incorporates some techniques that may be of limited interest to most in our specialty. Nevertheless, an understanding of these procedures is required if we are to communicate effectively with our colleagues and secure for our patients state of the art medical care.

Bronchoscopy

Flexible bronchoscopy

The flexible bronchoscope has opened the lung to our study as no other instrument in modern times. Not surprisingly, it has led to a surge of interest by physicians in many specialties. Scientific development in this field are reported in publications not often read by most in our own specialty; therefore the serious student of bronchoesophagology must read literature outside our own journals to remain abreast of important progress in diagnostic and therapeutic techniques.

Indications

Flexible bronchoscopy should be considered whenever a bronchopulmonary condition cannot be adequately assessed by other means. It may be indicated during the preoperative workup for an upper aerodigestive tract malignancy and is frequently used for treatment of bronchial obstruction, including selected foreign bodies.

Flexible instrument versus rigid instrument

The flexible instrument is preferred for adult *diagnostic* procedures, but the open tube rigid bronchoscope retains its value in the treatment of airway obstruction. Although in children, the open tube rigid bronchoscope is more often required for both diagnostic and therapeutic procedures, the flexible fiberscope is increasingly used as a complementary instrument.

Equipment

The choice and variety of equipment needed will depend on whether a broad range of diagnostic and therapeutic interventions is planned as opposed to a more limited investigation. Fiberscopes are available in several sizes for use both in adults and children. The insertion tube of the standard adult fiberscope is approximately 6 mm in diameter with an instrument channel of approximately 2.2 mm. A therapeutic bronchoscope provides a larger instrument channel (2.6 to 2.8 mm) in exchange for a smaller image and slightly larger external diameter. This instrument would be needed for Neodymium:YAG laser use, placement of certain brachytherapy devices, and use of some of the larger foreign body forceps. A fiberscope having an instrument channel of 3.2 mm diameter is also available and accommodates a larger selection of forceps. Minimum additional equipment includes appropriate light sources, biopsy forceps, and cytology brushes. An observer tube, xenon light source, and photographic and video equipment can also be added if desired. A video bronchoscope is now available providing an image from a chip located at the distal end of the instrument (Fig. 121-1). This instrument provides images of superb quality but requires the operator to perform the procedure by viewing a high-resolution video monitor. The insertion tube of the current instrument is somewhat larger than the diagnostic fiberscope and has a slightly smaller instrument channel (2 mm). This is an excellent documentation tool and a fine teaching device. It seems likely that this technology will eventually replace the standard fiberscope.

Technique

Every diagnostic bronchoscopy should be approached with a full understanding of the principal question to be addressed in light of the available laboratory and clinical evidence. It is highly desirable to understand what treatment options may be considered, especially in the event that a malignancy is discovered. One should be prepared to obtain not only an adequate biopsy but also additional information that may be needed by others to permit definitive care.

The fiberoptic bronchoscope is usually used with the patient under local anesthesia with sedation. We perform this procedure in the operating room and from the head of the table just as with rigid instruments. An anesthesiologist provides sedation and appropriate monitoring. Fentanyl and midazolam are frequently used in addition to a drying agent. Oxygen by nasal cannula (placed between the teeth) lessens the risk of hypoxia. Nasal anesthesia can be achieved by the use of topical cocaine or lidocaine applied with a small cotton applicator and placed along the floor of the nose. If the nasal airway proves too small, the procedure can be performed through the mouth with a bite-block to prevent damage to the instrument. This approach results in more stimulation of the gag reflex and is somewhat

more difficult since the tongue and oral secretions may obscure the view early in the procedure. For nasal insertion, the fiberscope should be lubricated with viscous lidocaine, both to reduce the friction and to facilitate anesthesia.

The instrument should be held in the left hand while the right hand is used to guide the tip of the fiberscope into the nose. The instrument is gently passed along the nasal floor to the nasopharynx where the tip of the bronchoscope is angulated downward to permit exposure of the epiglottis. Care should be taken to note any evidence of nasopharyngeal tumor. Two milliliters of 2% lidocaine should be drawn into a 5 mL syringe with about 2 cc of air to permit a full discharge of the agent into the larynx. The bronchoscope should be advanced approximately 1 cm and an additional instillation achieved as nearly as possible into the glottis. Over a period of several minutes three of four instillations should provide anesthesia adequate to suppress the cough reflex. In a well-sedated patient the local anesthesia requires no more than 5 to 10 minutes. The fiberscope can then be advanced into the trachea. Care should be taken to carefully assess laryngeal appearance and function. Additional anesthetic should be instilled into the left main bronchus, which may be less anesthetized than the right. The upper lobes are frequently not adequately anesthetized without direct instillation since gravity limits exposure to agents instilled into the trachea. Care should be taken to avoid developing complex curves in the shaft of the fiberscope to maintain a correct orientation of the distal tip.

The surgeon should proceed in an expeditious manner with the intent to complete the examination in no more than 20 minutes if possible. When the effect of local anesthesia begins to wear off and the cough returns, there may be no way to provide satisfactory working conditions without resorting to a general anesthetic. The application of additional topical agent may be of no benefit as secretions begin to increase with cough.

If there is a localized radiographic change, attention should be directed first to that area before examining the remainder of the bronchial tree. Following retrieval of all necessary specimens the examination may be completed as indicated.

Endotracheal tube insertion

The fiberoptic bronchscope may be used to aid in the insertion of an endotracheal tube or to insert a bronchoscope into a patient already intubated. Whenever the fiberscope is used in this way, the entire shaft of the instrument should be well lubricated to reduce friction between the instrument and the tube. An endotracheal tube of appropriate size may then be loaded onto the fiberscope and held in place by the pilot tube (Fig. 121-2). The instrument can then be placed through a bite-block into the mouth. When the fiberscope reaches the lower trachea, the endotracheal tube can be slipped off the bronchoscope and into the airway. Care should be taken to maintain the orientation of the tube so that its natural curvature is positioned appropriately. This is easier to achieve if the surgeon stands in front of the patient. For patients using a ventilator a T adapter will be used to facilitate continued ventilation during the procedure (Fig. 121-3). A No. 8 or 9 endotracheal tube is adequate to allow the standard fiberscope to pass without serious interference with ventilation for a short procedure.

Specimen retrieval techniques

No biopsy speciment should be attempted until a careful visual assessment has been made regarding the specific location of the lesion and a determination of the approximate distances from major landmarks. Bleeding may obscure some relationships important in determining further care.

Brush biopsy. A cytology brush should be applied to areas of suspicion for tumor (Fig. 121-4). The brush must be maintained within its protective sheath until near the point to be sampled, then extruded from the sheath, and then passed into the involved site several times before withdrawing the brush back into the protective sheath. The brush may then be withdrawn from the fiberscope and the specimen placed in saline for prompt transport to the cytology laboratory. For maximum specimen retrieval we prefer a small pick to physically dislodge the specimen from the brush into saline solution. Alternatively, the specimen may be smeared on a glass slide and fixed in Papanicolaou's solution.

Biopsy forceps. Biopsy forceps should be passed through the lumen of the fiberscope while the shaft of the instrument is well proximal to the site to be sampled. Nothing can be more frustrating than to obscure the lesion either by dislodging a glob of mucus or by bleeding through inadvertent forceps trauma before the surgeon is prepared to obtain a specimen. I frequently flush the instrument channel with saline before passing the forceps to avoid the mucous problem. If the lesion is very small and relatively difficult to reach, one may choose a forceps biopsy before using the brush since forceps must be more precisely positioned than the brush to achieve a diagnostic specimen. Several specimens should be obtained from the area of suspected tumor since superficial necrosis often obscures diagnostic tissue. Finally, the lesion should be irrigated with saline to provide additional material for cytologic examination.

Whenever it appears that a pulmonary resection is likely, it may be helpful to obtain additional biopsy specimens to rule out inappropriate tumor spread into sites where the resection might occur. For example, a tumor in the right upper lobe may be located so as to make a lobectomy feasible. A biopsy from the right upper lobe spur and the carina will help establish whether superficial tumor extends more proximal than can be appreciated. The same forceps used to obtain tumor tissue should not be used for marginal biopsies since small tissue fragments may remain on the forceps to create a false-positive diagnosis.

Bronchoalveolar lavage. Bronchoalveolar lavage is a form of cell sampling frequently used to obtain specimens from peripheral areas of the lung. This procedure may be used not only for suspected malignancy but also for inflammatory lung disease (Baughman et al, 1991). One of its more frequent applications today is for the diagnosis of *Pneumocystic carinii* pneumonia and other opportunistic infections seen in immunocompromised patients. The procedure is accomplished by wedging the fiberoptic bronchoscope into a segmental bronchus (usually within the right middle lobe). While the instrument is thus wedged, 50 mL of saline is instilled and then aspirated. Usually, about 40% can be retrieved. It may be necessary to instill 100 mL or more of fluid until an adequate specimen has been obtained. The aspirate can then be analyzed as required by cytopathology and microbiology laboratories.

Transbronchoscopic needle aspiration biopsy. Not infrequently in the study of pulmonary tumors it may be necessary to evaluate enlarged lymph nodes located in the mediastinum (Fig. 121-5). The needle aspiration technique permits such specimens by means of a special needle passed through the wall of the trachea or bronchi into the adjacent node-bearing areas (Harrow et al, 1989). Such studies are nearly always preceded by a CT scan to determine the most appropriate site but may be considered when tracheobronchial compression clearly identifies the site for biopsy.

After achieving satisfactory anesthesia the fiberscope should be positioned with the distal tip within the midtrachea. A sheathed 22-gauge needle can then be introduced until it just appears within the optical field (Fig. 121-6). At this point, the needle may be unsheathed and withdrawn into the instrument channel until just the bevel is visible. The exposed needle point will create serious damage to the bronchoscope if passed unsheathed through the instrument channel. The bronchoscope should then be angulated 90 degrees to the surface and brought into contact with the site for biopsy. at this point the needle should be grasped about 2 cm proximal to the instrument port and given a sharp jab. With downward pressure on the needle, the bronchoscope may then be slightly withdrawn to expose the insertion site to determine whether the needle has fully penetrated the wall. The nurse should then attach a 20 mL syringe containing a small amount of saline and apply maximum suction for several seconds. As the needle is withdrawn, the syringe vacuum may be released and the specimen deposited in a container with saline for prompt transport to the laboratory. The cytopathologist may be called to the operating room to perform a preliminary assessment of the specimen and determine the possible need for additional material. Three to four needle aspirations are recommended to obtain an optimal yield. The specimen is usually inadequate to permit analysis by surgical pathology unless a large caliber needle is used. Bleeding is usually brief and self-limited. A review of the mediastinal anatomy is recommended before using this technique. Major vessels, the pleura, and esophagus are nearby but with proper technique serious complications are extremely rare (Figs. 121-7 and 121-8). The diagnostic yield is high.

Transbronchoscopic lung biopsy. Transbronchoscopic lung biopsy is performed when lung tissue is needed in a diagnosis of diffuse or localized pulmonary conditions. In a case of localized disease, fluoroscopy may be required in selecting the bronchus that leads to the lesion site.

The fiberscope should be placed within the trachea or main bronchus until the biopsy forceps has been passed through the instrument channel and seen within the visual field. The bronchoscope can then be positioned as near to the biopsy site as possible. In the case of diffuse disease I prefer the right lower lobe where minimal angulation is required. This allows a delicate sense of touch helpful in avoiding complications. The forceps cup should be passed well into the periphery of the lung and just beneath the pleura. This position reaches beyond the larger branches of the pulmonary artery that accompany the bronchi. The risk of life-threatening hemorrhage is reduced by obtaining material as close to the pleura as feasible. Fluoroscopy can be used, but experienced endoscopists often achieve a satisfactory placement without it. My practice is to pass the forceps *no less than 4 cm* beyond the most peripheral site where it can still be seen through the bronchoscope. Additional insertion may then be made until a slight resistance occurs or the patient notes pain at the chest wall. The forceps jaws should be opened, slightly withdrawn, and then reinserted before the cups are closed. This maneuver enhances the likelihood that the cups have been successfully opened and

allows tissue to enter. The forceps is closed and slowly withdrawn. There should be very little resistance required to avulse the specimen. Otherwise, the biopsy may have been too proximal where cartilage has been grasped and where the risk of major hemorrhage is increased. In that case, it is best to release the forceps and try another site. When the specimen is obtained, it should be withdrawn slowly and the bronchus carefully observed for excessive bleeding. If that should occur, the bronchoscope can be wedged into the bleeding bronchus using the biopsy forceps as a stylet to guide the tip into the exact subsegment. The forceps can then be removed and the bronchoscope used to tamponade the bleeding site. This has rarely been necessary in my experience. Lung biopsy specimens should normally be obtained from several sites within the lobe to obtain a representative sample but never from both lungs. The risk of pneumothorax is small, but a bilateral complication might prove catastrophic.

Specimen handling. These specimens are very small. It is sometimes helpful to stain with a drop of eosin to aid specimen recognition in the laboratory. I prefer to place the speciment directly into a small container of formalin to reduce the risk of specimen loss. When this is done, however, greater care should be taken to rinse the forceps in saline before any further use is made of the device.

Postoperatively, a chest radiograph should be obtained (preferably several hours later to detect the onset of a slowly developing pneumothorax). This complication occurs in perhaps 2% to 3% of patients undergoing this procedure, and some require the insertion of a chest tube.

Laser use with fiberoptic bronchoscope

Considerable interest has developed in the use of lasers for treatment of assorted tracheobronchial lesions. The neodymium:YAG (Nd:YAG) laser is doubtless the most efficient and versatile instrument for use in the treatment of obstructing tumors. Other lasers that can be conducted by a fiber through the instrument channel of the flexible bronchoscope include the potassium titanyl phosphate (KTP/532) and argon lasers. Use of such devices requires a thorough knowledge of laser-tissue interaction and safety procedures to avoid the risks of life-threatening airway injuries.

Indications

Intraluminal tracheobronchial tumor obstruction. Laser use should be considered only in the context of an overall treatment plan. The Nd:YAG laser is usually used for recurrent tumors involving the trachea or main bronchi and must be considered only palliative for obstructive symptoms. It may be indicated for an occasional airway obstruction before the use of radiation therapy or other measures. Great care should be taken to select those patients for treatment whose quality of life is most likely to be improved by this procedure and whose alternatives are limited. These patients are often in a precarious condition, necessitating a frank discussion of the risks and benefits expected. It is contraindicated in tumor obstruction from extrinsic compression and relatively contraindicated in upper lobe tumors. Its use in segmental bronchi is seldom justified since the risks usually outweigh any benefit. The Nd:YAG laser can be more efficiently used in many cases by means of a special laser rigid bronchoscope, but with care and patience its use with the fiberscope presents a reasonably safe and effective alternative (Chan et al, 1990).

Localized stenosis. The carbon dioxide laser is usually preferred for localized stenosis; however, when mechanical factors do not permit access to the lesion, an Nd:YAG laser passed through a fiberscope may be considered.

Suture granuloma. Exposed sutures in the airway (such as following pulmonary resectin) may result in cough and hemoptysis from a localized granuloma. The Nd:YAG or KTP/532 laser may permit suture removal and ablation of the granuloma.

Technique. The patient may be positioned either supine or semireclining and should be carefully monitored. Everyone in the room including the patient must weal wavelength-specific protective goggles. The laser should be calibrated and test fired. Initial setting should be 25 to 40 watts and 0.5 to 1 seconds in the intermittent mode. The Nd:YAG laser is never used in the continuous mode in the tracheobronchial tree. The procedure can be performed with the patient under either local or general anesthesia. Oxygen levels must be kept as low as the patient's condition will permit since levels above 40% increase the risk of fire.

Local anesthesia. A therapeutic fiberoptic bronchoscope having an adequate channel size can be introduced either nasally or orally as described early in this chapter. The laser fiber should be carefully introduced to a point just beyond the tip of the fiberscope and well within the visual field. I find it helpful at this time to attach a piece of paper tape to the laser fiber at the entrance to the instrument channel to permit rapid removal and replacement to a predetermined point. Blood must not be permitted to contaminate the fiber tip since laser heat will destroy the fiber. The fiberscope should be positioned so that the laser fiber is approximately 1 cm from the tumor. Brief bursts of laser energy can then be observed as the instrument is brought closer to the lesion. Great care must be taken to assure that the laser is never fired while the fiber is within the instrument channel. This will destroy the bronchoscope and may injure the patient as well. The desired effect is blanching of the tumor so as to coagulate the vessels. If the power density is too high, vaporization may take place, resulting in bleeding. This is difficult to manage since the instrument channel is occupied with the laser fiber and suction cannot be used independently. After the surface of the tumor is coagulated, some vaporization may be achieved by approximating the tumor more closely. The objective is to treat the narrowest part of the airway in order to improve the lumen as soon as possible. Some degree of swelling may occur but is usually more than offset by tissue removal. The axis of the laser beam should be relatively parallel to the bronchus wall to limit the risk of structural damage with subsequent necrosis and hemorrhage. After adequate coagulation portions of the tumor may be removed with a biopsy forceps. This is a tedious process in a large tumor, but even minimal airway improvement provides welcome relief and may allow radiation therapy or a subsequent laser procedure to achieve further improvement. Finally, the area should be lavaged with saline to remove laser debris. Careful monitoring in the postoperative period is imperative.

General anesthesia. Although local anesthesia is often sufficient, when the cough cannot be adequately suppressed, general anesthesia may be considered. A large, *clear* endotracheal tube is required to permit adequate ventilation around the fiberscope. A bite-block or an oral airway should be placed between the teeth to guard against possible instrument damage if light anesthesia should result in a bite on the endotracheal tube. The proximal end of the endotracheal tube should be cut off sufficient to reduce its length to the minimum necessary. This serves both to lessen the resistance to passing the fiberscope and

to maintain the distal end of the tube as far away as possible from the treatment site. A T adapter makes a convenient means of controlling the airway during the procedure. Water-soluble jelly and a silicone spray applied to the fiberscope make the instrument passage quite satisfactory. The endoscopist must first determined that the tip of the endotracheal tube is well proximal to the tumor site. The fiberscope must then be positioned at least 2 cm distal to the endotracheal tube to eliminate the risk of tube ignition. The use of a helium oxyhen mixture (Heliox) is further recommended to enhance safety. The anesthesiologist must be fully informed regarding the necessity for maintaining oxygen concentrations as low as compatible with maintaining a satisfactory oxygen saturation. The laser procedure can be performed as described with the patient under local anesthesia. This technique has the advantage of a quiet operating field with assured ventilation and a comfortable patient but requires vigilance to minimize risk.

Brachytherapy

Nd:YAG laser debulking of intraluminal major airway tumors has contributed to renewed interest in endoscopic palliation. Unfortunately, improvement after laser treatment alone is often of short duration (about 3 months), and repeated treatment becomes less successful as the tumor extends. The laser is also of limited use in the upper lobe tumors where risks of bronchus penetration often outweigh any possible benefit. Depending on such variables as performance status, extent of disease, life expectancy, and location of tumor some patients may benefit from bronchoscopic palliation with brachytherapy (Marsh, 1989; Mehta et al, 1989). *Brachy* means short. Brachytherapy refers to that form of radiotherapy with a short distance between the radiation source and the target (for example, radioisotope implants). Even though the patient has already received full-course external beam radiation therapy, additional palliation can frequently be achieved by one of several brachytherapy techniques. The prior use of laser debulking does not preclude the use of brachytherapy nor does it enhance efficacy. Brachytherapy provides a means for deeper penetration of the tumor-bearing airway than can safely be achieved with laser yet has little effect on pulmonary parenchyma. Such treatment appears to prolong the duration of palliation achieved by laser treatment alone.

High-dose rate. Iridium 192 may be used as an afterload technique in which the endoscopist places a special catheter or catheters through the tumor site and secures them at the nose. These catheters can be positioned through the channel of the therapeutic fiberscope using standard local anesthesia techniques. The patient can then be transferred to the radiation therapy department where the isotope source is placed in the catheter, and after a predetermined time it is removed. This procedure may need to be repeated on three occasions at weekly intervals to deliver a satisfactory dose. This technique has the advantage of very little airway threat even with large tumors and can be used in the upper lobe or after pneumonectomy. Excellent coordination with the radiation oncologist is required. Occasionally, the catheters are coughed out of position before the treatment is completed.

Low-dose rate. Iodine 125 is well suited to bronchoscopic use since radiation risk to the operating room staff is minimal, and no special shielding is required on the ward.

Interstitial implant. Iodine 125 seeds can be distributed at approximately 0.5 cm intervals throughout a bronchial tumor bed and deep enough to prevent early expectoration. The rapid dropoff in dosage with distance from the implant contributes to both its safety and its limited depth of effective penetration. Interstitial brachytherapy is technically demanding and requires excellent anesthesia, special instrumentation, and support from radiation oncology, but the results in properly selected patients can be gratifying. We have used from 3 to 30 seeds depending on the tumor extent. Some tumors (especially in the upper lobe) can be implanted with the fiberscope and special insertion equipment with the patient under local anesthesia, whereas others are better managed with the patient under general anesthesia with the rigid bronchoscope and a long needle with a stylet for driving the implant into position (Figs. 121-9 and 121-10).

Temporary implant. We have developed a new implant capsule for insertion and retrieval by the fiberscope with the patient under local anesthesia (Figs. 121-11 and 121-12). This device is preloaded by the radiation technical staff and permits treatment of major airway tumors to 5000 rads in 3 days without significant radiation risk to the staff. It is well tolerated, and none have been coughed out. In properly selected patients palliation can be provided for several months.

Foreign body applications

The fiberscope may be used for retrieval of some airway foreign bodies in adults and older children. It is particularly useful for segmental, small objects difficult to manage with open tube instruments and may also be useful in some relatively nonobstructive foreign bodies of the trachea or major airways. This procedure should be considered especially in cases where cervical or maxillofacial deformities or injuries make the open tube difficult to use or where general anesthesia may be contraindicated.

The selection of foreign body forceps for use through the fiberoptic bronchoscope remains limited but is increasing as larger channel instruments become available (Fig. 121-13). Airway foreign body endoscopy requires a large armamentarium of open tube instruments and broad training. Nevertheless, our experience and that of others clearly show that there is an increasing role for the fiberscope in carefully selected cases (Lan et al, 1989; Limper and Prakash, 1990).

Open tube bronchoscopy

Indications

The rigid bronchoscope is seldom required for diagnostic studies in adults but retains its value for a number of therapeutic applications: laser use, removal of bulky tumors, introduction of radioactive materials, removal of foreign bodies, and placement of stents and other conditions requiring the mechanical features permitted by this equipment. Pediatric airway investigations often require its use.

Equipment

Several companies manufacture high-quality, fiber-illuminated bronchoscopes with rod optics telescopes and related equipment. The selection is largely a matter of personal preference but must include all necessary illumination devices, adapters, aspirating tubes, tube caps, forceps, and telescopes in appropriate sizes. The bronchoscope selected should be supplemented by one of a smaller size in the event of a smaller than anticipated airway. A larger tube is needed if positive pressure ventilation is planned. One might select a No. 8 or 9 bronchoscope for an adult male and one size smaller for an adult female. The decision will be influenced not only by the size of the patient's larynx but also by the location and nature of the task to be accomplished. A smaller instrument may be needed for a lesion in the lower lobe than for one in the trachea or main bronchus.

Technique

In contrast to techniques in common use 25 years ago this procedure is almost universally performed with the patient under general anesthesia. There are several satisfactory methods for accommodating the needs of both endoscopist and anesthesiologist. The patient should be positioned supine with the head even with the end of the operating room table equipped with a moveable headpiece. I prefer to place a folded sheet under the head, raising the occiput above that provided by the moveable headpiece alone. After the patient has been anesthetized and appropriate eye protection applied, the head should be extended by traction on the maxilla with the left hand and pressure on the occiput by the right hand. This achieves flexion of the cervical spine and extension of the head. While holding the position with the left hand, the bronchoscope is introduced with the right hand. The instrument is initially held almost vertically until it reaches the posterior pharynx where it is gradually moved to a more horizontal position. The fingers of the left hand cradle the bronchoscope like a billiard cue, providing protectin for the upper lip while the thumb maintains anterior pressure protecting the upper teeth. A moist sponge or plastic tooth guard placed over the maxillary teeth provides additional protection. The right hand maintains directional control over the instrument while the left thumb is used to advance it into the airway. Those lacking youthful vision discover that an indwelling telescope aids in recognition of laryngeal structures and greatly enhances one's confidence. Elevation of the tip of the epiglottis may be tricky, and in a stocky, thick-necked person with a full set of teeth, it may be necessary to vigorously extend the head while further flexing the neck to achieve entry into the glottis. This maneuver can be facilitated by the adept use of the surgeon's left hip pressing against the head. Once the glottis is seen, the bronchoscope can be passed between the vocal cords and into the trachea where ventilation may be resulted either by positive pressure or jet techniques. The headpiece provides optimal illumination and magnification for the main and lower lobe bronchi, whereas angulated telescopes may be needed for the upper lobes and superior segments of the lower lobe. The right hand is used to manipulate the head so as to direct the tip of the bronchoscope as necessary to explore the major airways bilaterally and without undue trauma. The left thumb at all times maintains anterior pressure to avoid dental injury and to facilitate axial control of the bronchoscope. When biopsies are required, care should be taken to avoid deep penetration of bronchial spurs. Never should two biopsy specimens be obtained from the same spur since risk of hemorrhage is too great. When the procedure is completed, the bronchoscope should be brought back to the lower trachea until the anesthesiologist approves its removal and takes control of the airway.

Pediatric Bronchoscopy

Remarkable advances ni endoscopic equipment and anesthesia have nowhere been more welcomed than in the assessment of the pediatric airway. Nevertheless, greater sophistication in equipment demands that the endoscopist and staff be fully trained in its use separately and as components of a large number of instruments required to meet the varied needs of this work. Questions about which instrument is best are less important than the skill and training of the team.

Flexible fiberoptic bronchoscopy

Indications

The fiberscope should be considered whenever there is a need to evaluate airway function with the patient under local anesthesia. It may also be used to evaluate the tracheobronchial tree for such conditions as cough, recurrent pneumonia, and unexplained infiltrates. In the hands of a fully trained and equipped endoscopist, flexible fiberoptic bronchoscopy may be used to evaluate the airway of a child in whom there is a suspicion of foreign body. This should be considered only when one is prepared to proceed immediately with open tube technique for foreign body management. Instrumentation for foreign body management with the fiberscope is very limited but occasionally useful for older children. These procedures should be performed by those with a special interest in the pediatric airway and a broad knowledge of both diagnostic and therapeutic options. It is not a procedure to be undertaken lightly by the occasional operator.

Equipment

Pediatric fiberscopes are now available in a number of sizes. The most clinically useful has an external diameter of approximately 3.7 mm and a channel size of about 1 mm. Smaller-diameter fiberscopes currently available have no channel, and the smallest ones approximating 1 mm in diameter have no directional control. An instrument of approximately 5 mm in diameter provides a larger instrument channel needed for certain forceps and more effective secretions management. A selection of bronchoscopes, light sources, and suction traps is required for optimal service.

Technique

Flexible fiberoptic bronchoscopy should be performed in the operating room with the aid of an anesthesiologist who is in charge of monitoring and sedation. An anesthesiologist familiar with the special requirements of the pediatric patient will prove a considerable benefit. When adequate sedation has been achieved the nose should be anesthetized with lidocaine. Supplemental oxygen is usually delivered by a small cannula. The fiberscope is then lubricated with viscous lidocaine and passed very carefully through the nose into the pharynx. If the nasal route proves unacceptable the instrument may be passed orally through a bite-block. This requires that the bite-block is securely stabilized to avoid displacement and severe instrument damage.

The operator stands at the head of the table while someone steadies the head. The

instrument should be held in the left hand and gently and slowly advanced with the right hand. As the instrument reaches the nasopharynx the tip is angulated downward to expose the larynx. At this point, lidocaine may be instilled through the instrument channel for topical anesthesia of the larynx and lower airway. The instrument can then be passed through the glottis into the trachea. This procedure should be completed expeditiously, especially in small children. An adequate examination is usually well tolerated, and one can quickly determine whether it may be necessary to proceed with an open tube with the patient under general anesthesia. The procedure may be performed with general endotracheal anesthesia in children intubated with a 4.5 mm or larger endotracheal tube. In this case, the fiberscope must be well lubricated to reduce friction.

Foreign body applications

The fiberscope may be considered for retrieval of non-obstructive, metallic or plastic, relatively nonreactive airway foreign bodies in older children. An instrument of approximately 5 mm in diameter is required to include a lumen large enough to permit use of available foreign body instruments. For adolescents and adults, instruments of approximately 7 mm diameter are equipped with larger channels greatly expanding the selection of foreign body instruments available (see Fig. 121-13). The availability of fiberscopes possessing foreign body potential is in itself not to be construed as a recommendation for their frequent use. The well-trained endoscopist must review the technical problems to be overcome and make a decision based on best judgment of which instrument or combination of instruments might be the most appropriate for the case at hand. As new instruments are introduced, we must always compare them with traditional methods of proven efficacy and safety.

Open tube bronchoscopy

Indications

Airway obstructions usually demand the availability of open tube instruments with telescopes and ancillary equipment for proper use. This equipment is also best suited to investigation of anomalies where magnification is needed.

Equipment

A full complement of modern fiber-illuminated bronchoscopes with rod optics telescopes is required. Appropriate laryngoscopes must also be on hand as well as a number of related pieces including light sources, light guides, aspirating tubes, adapters, caps, forceps, laser, microscope, tooth guards, and eye shields.

Technique

Most open tube bronchoscopy is performed with the patient under general anesthesia in the operating room. An experienced pediatric anesthesiologist is most helpful in tailoring the anesthetic technique to the endoscopists's special demands. A preoperative discussion between the two should outline the plan and whatever backup options may be considered. A careful assessment of the risks should be made, including an evaluation of the teeth.

The approach to intubation varies with the specific plan. If I am working with an anesthesiologist with whom I am unacquainted or who has little experience in endoscopic anesthesia, I may suggest intubating the patient in the normal way and getting things stabilized before turning over the airway. At that time the bronchoscope can be positioned in the region of the anterior commissure and secretions aspirated. The telescope may be inserted to view the airway while the endotracheal tube is slowly withdrawn. As soon as the glottis is clear, the bronchoscope can then be slipped into the trachea. When working with our regular anesthesia team or when there is concern about the larynx or cervical trachea, the patient is anesthetized and ventilated by mask until ready to be turned over to the endoscopist. At that point I prefer to expose the larynx with an anesthesia laryngoscope unless I am using a No. 4 or larger bronchoscope. The nurse hands me the bronchoscope with an indwelling telescope positioned just so as to demonstrate the circumference of the distal end of the bronchoscope. This provides not only an excellent view of the airway but also a comparison between the size of the bronchoscope and the adjacent lumen. This technique is especially helpful in evaluating airway stenosis. The anesthesiologist then resumes ventilation via a Jolly tube connected to the bronchoscope. Head position for these maneuvers is similar to that described for the adult. In an infant or child, however, I find it unnecessary to use an elevating pad under the occiput. When the bronchoscope has been positioned within the trachea, the left hand maintains security at the upper teeth while the right is used to manipulate the head, telescope, suction, and other instruments as needed. The head is moved to the left to permit passage into the right main bronchus, and it is moved to the right and elevated slightly to explore the left main bronchus. Each of these maneuvers is accompanied with the telescope just proximal to the distal end of the bronchoscope. This permits the least tissue trauma and most useful view as the bronchoscope is moved from place to place. For examination of the lobar and segmental bronchi the telescope may be further introduced into the smaller airways to obtain a more complete assessment where feasible. Note should be made of inflammation, abnormal secretions, anomalies, areas of compression or malacia, edema, airway obstruction, and foreign bodies. If necessary, one can obtain specimens for culture, cytologic analysis, immotile cilia, and so on. When the procedure is completed, the bronchoscope should be removed with the approval of the anesthesiologist who will determine whether or not the child is to be intubated until awake. Observation in a well-staffed recovery room should be required until the patient is fully recovered from anesthesia.

Esophagoscopy

Flexible esophagoscopy

Indications

Esophagoscopy plays an important role in the evaluation of patients with upper aerodigestive tract malignancies as well as dysphagia, odynophagia, causing ingestion, foreign bodies, trauma, and suspected anomalies. This procedure is potentially hazardous and requires not only great technical skill but also careful attention to the preoperative workup including contrast studies, condition of the jaw and cervical spine, and general status.

Flexible instrument versus rigid instrument

Most *diagnostic* esophagoscopy is now performed with flexible instruments for which use they are vastly superior to rigid tubes except in the upper esophagus. For some types of therapy, including foreign body removal, rigid instruments may be preferred, but recent developments in flexible instruments require an open mind regarding such concerns. Use of the rigid instrument can be difficult and dangerous, especially in aged persons with hypertrophic changes in the cervical spine or with limited spine mobility or in thick-necked persons with a full set of teeth. These features suggest use of the flexible instrument. The otolaryngologist-head and neck surgeon should be facile with both types of instruments to provide the safest, most effective study for patients.

Technique

The flexible instrument is usually introduced with topical anesthesia and sedation. The patient should be placed in a flexed position on his side to facilitate both instrument passage and control of secretions and airway. A bite-block should be placed between the teeth and secured to protect the instrument from being bitten. The fiberscope should be lubricated before being passed through the bite-block and into the pharynx when the patient is asked to swallow to facilitate passage through the cricopharyngeus. This part of the examination should be conducted with careful visualization of landmarks just as one would do with a rigid instrument. The older technique of blind insertion through the pharynx into the cricopharyngeus should be abandoned. Intermittent depression of the air/water and suction valves permits a clear view of the inflated organ, enhancing a safe and detailed study of the esophagus (and stomach if desired).

If the procedure is performed with the patient under general anesthesia, the patient remains supine while the larynx is elevated with an anesthesia laryngoscope to simplify passage of the instrument through the cricopharyngeus. The endotracheal tube cuff may be temporarily deflated.

Specimen retrieval techniques

If malignancy is suspected, both a brush specimen for cytology studies and several cup forceps specimens for histologic studies may be obtained. The sites of any lesions or specimens should be recorded by measurement from the upper teeth and regional anatomy to aid in providing further care.

Foreign body applications

The rigid esophagoscope remains the standard against which to measure the results of all other techniques for foreign body removal (Hawkins, 1990; Holinger, 1990). Nevertheless, endoscopists experienced with flexible instruments continue to develop new instruments and methods of handling esophageal foreign bodies (Webb, 1988). Many reports of successful foreign body removal have resulted from these efforts. Through the use of "over-tubes" even large, sharp objects have been successfully retrieved. The otolaryngologist-head and neck surgeon should become familiar with these developments.

Rigid esophagoscopy

Technique

General endotracheal anesthesia is preferred for nearly all patients. A completely relaxed patient permits the procedure to be conducted with less force and less risk of instrumental perforation. The patient is positioned supine with the head and shoulders over a mobile headpiece. The head should be elevated so as to flex the neck while, at the same time, the head is extended on the neck. A moist gauze sponge should be placed over the upper teeth to provide some measure of protection. The esophagoscope should then be introduced along the right side of the tongue using the left hand to cradle the instrument as a billiard cue. The fingers retract the upper lip while the thumb provides both anterior pressure to avoid dental injury and axial force for insertion of the instrument. The righ hand stabilizes the proximal end of the instrument and is used for suction, telescope insertion, air insufflation, and so on. The lip of the esophagoscope should be positioned anteriorly to permit elevation of the tip of the epiglottis in such a manner as to expose the right arytenoid and piriform sinus into which the instrument is then passed. Care should be taken to ensure the correct axis of the instrument. A small esophageal bougie (10F) may be passed through the cricopharyngeus into the esophagus as a guide for further introduction of the instrument. Its purpose is not to act as a stylet over which to force the instrument. Firm anterior pressure is required to overcome the resistance of muscular pull on the overlying larynx. Complete relaxation and perfect position are required to avoid perforation, which most often occurs in the upper esophagus. "Safety requires that the mind of the beginner be impressed with the fact that the pathway of the esophagoscopist is beset with pitfalls for the unwary" (Jackson and Jackson, 1950). As soon as the lumen of the esophagus has been entered, the bougie should be removed and the headrest lowered. The left thumb can then be used to advance the instrument while the right hand is removed from the instrument and placed on the head to provide moment to moment control of the relation between the distal tip of the instrument and the axis of the lumen. As one reaches further into the thorax, the head and shoulders must be further extended to straighten out the thoracic spine and allow the esophagoscope to follow the esophagus anteriorly. In the lower one third, the esophagus turns strongly to the left so that as it approaches the gastroesophageal junction the instrument should point in the direction of the left anterosuperior iliac spine. Telescopic magnification and simultaneous air insufflation add greatly to identification of less apparent pathologic conditions. Gentle technique and a clear lumen ahead are essential to avoid perforation. Many congenital and acquired conditions occur in this area, and a thorough understanding of the radiographs is a prerequisite to this study. It is not always possible or necessary to see the gastric mucosa with a rigid esophagoscope, even though this can usually be achieved if indicated. It is no disgrace if one fails to complete the study in order to avoid the risk of a catastrophic perforation. A filiform bougie can be introduced through the lower esophageal sphincter to aid in determining the correct axis just as was done at the cricopharyngeus.

Although no significant lesion may be identified during insertion of the esophagoscope, a careful search should be made during withdrawal of the instrument. Many times one discovers something not appreciated during insertion. Mucosal folds may have obscured a significant lesion from view, but during withdrawal of the instrument the folds are flattened out, permitting an unexcelled examination. During the withdrawal process the head and shoulders are gradually returned to their initial position, duplicating in reverse the process

of insertion.

Speciment retrieval

Cytology specimens may be obtained from any suspicious lesion. Biopsy specimens should be obtained not only from an apparent tumor but also proximal to the lesion. Primary esophageal tumors frequently extend submucosally for a considerable distance, and such specimens aid in determining definitive care.

Foreign body applications

Esophageal foreign bodies are often best removed with a rigid esophagoscope in a patient anesthetized with general endotracheal anesthesia. A radiograph should be obtained immediately before induction of anesthesia to ascertain whether the foreign body has moved. In children, coins frequently lodge at the cricopharyngeus and can easily be removed with a forward grasping forceps. One should not forget, however, that coins and other foreign bodies can be completely hidden from view by the downward folding of the cricopharyngeal mucosa as the instrument overrides the foreign body. Special care should be exercised to examine closely the posterior wall of the cricopharyngeus during removal of the instrument.

Postoperative care

The mouth should be inspected for evidence of dental injury. If one is concerned about the possibility of instrumental perforation of the esophagus, a contrast study should be obtained as soon as the patient recovers from anesthesia, and a thoracic surgical consultation should be requested. If there is no reason to suspect a complication the patient should, nevertheless, be instructed to report immediately any untoward symptoms such as chest or back pain or fever.