Bronchoscopy is currently the most commonly employed invasive procedure in the practice of pulmonary medicine. Both the rigid and flexible bronchoscopes are used to diagnose and treat various pulmonary disorders. The main diagnostic indications include pulmonary involvement by neoplasms, infections, diffuse lung diseases, and airway problems. Bronchoscopic needle aspiration remains an underutilized technique in the staging of lung cancer. Newer techniques such as bronchoscopic ultrasound appear promising and may lead to improved diagnostic yield from bronchoscopic procedures. The bronchoscope is used in application of laser therapy, brachytherapy, electrocautery, cryotherapy, placement of airway stents, and balloon dilatation to relieve airway obstruction caused by malignant and benign airway lesions.

The technique and clinical application of bronchoscopy had their origins in 1897, when Gustav Killian of Freiburg, Germany, used a rigid endoscope to examine the airways. Chevalier Jackson of Philadelphia refined the rigid bronchoscope, which was the only type of instrument available for the evaluation of airways until the early 1970s, when Shigeto Ikeda developed the flexible fiberoptic bronchoscope and introduced it into clinical use. Subsequent refinements in both rigid and flexible bronchoscopes and ancillary equipment have significantly improved the diagnostic and therapeutic potential of bronchoscopy. Development of newer concepts in the diagnosis and treatment of pulmonary diseases has led to increased clinical applications for bronchoscopic procedures. As a result, bronchoscopy is perhaps the most commonly used invasive diagnostic and therapeutic procedure in pulmonology. This paper provides a brief overview of several types of bronchoscopic procedures, sometimes described as “interventional bronchoscopic procedures,” and their advantages and disadvantages.

Basic Instrument

Both the rigid and flexible bronchoscopes have undergone many modifications. The newer modifications in the rigid bronchoscope have established it as the ideal instrument for debulking of large tumors in the major airways, dilatation of tracheobronchial strictures, laser bronchoscopy, insertion of airway prostheses (stents), and extraction of tracheobronchial foreign bodies. The flexible bronchoscope is used in >95% of all bronchoscopic procedures. Indeed, there are very few bronchoscopic procedures that cannot be accomplished with the flexible bronchoscope. Presently, many ancillary instruments are available to accomplish various diagnostic and therapeutic procedures via the flexible bronchoscope. Ultrathin flexible bronchoscopes permit inspection of airways in infants and neonates. Flexible bronchoscopes with a larger working channel enable the bronchoscopist to insert larger biopsy forceps, balloon catheters, laser fibers, and other instruments into the airways to obtain larger and better-quality biopsy specimens.

The traditional fiberoptic bronchoscope is gradually giving way to videobronchoscope. The latter is a flexible bronchoscope equipped with a charge-coupled device at its distal tip. The bronchoscopic images are digitally captured and transmitted to a video processor for display on a television monitor. The advantage is that the excellent images can be simultaneously visualized by many, making it an excellent tool for teaching purposes. The images can...
also be stored in several digital formats. The disadvantages include the added expense of purchasing video equipment and a computer terminal, and the larger working and storage space required. The major drawback is the loss of ability to view the image through the headpiece of the flexible bronchoscope; the bronchoscopist has to depend on the video monitor to visualize bronchoscopic findings. The image on the monitor is only as good as the monitor. The traditional fiberoptic instrument remains very valuable for direct visualization of airways.

**Diagnostic Bronchoscopy**

Routine bronchoscopic visualization to detect endobronchial abnormalities, BAL for the identification of many infectious and certain noninfectious lung diseases, and the use of bronchoscopy in brushing and biopsy of both visible airway lesions and bronchoscopically invisible parenchymal lung lesions are standard practice. The following discussion pertains to certain diagnostic procedures not routinely performed by all bronchoscopists.

**Bronchoscopic Needle Aspiration**

Bronchoscopic needle aspiration (BNA) of lymph nodes located in the paratracheal, subcarinal, and perihilar areas is useful in the diagnosis and staging of thoracic malignancies. The technique can also be used in the diagnosis of endobronchial lesions that are submucosal\(^4\) and peripheral nodules and masses. The bronchoscopic needle has been used to drain bronchogenic and mediastinal cysts located adjacent to major airways. Although BNA is easy to learn and perform, it remains underused by bronchoscopists.\(^5,6\) The aspiration needle is available in 19-gauge, 20-gauge, and 21-gauge sizes and can be inserted through the working channel of the flexible bronchoscope. The diagnostic rate for non-small cell carcinoma has ranged from 43 to 83%.\(^5,7\) Complications are rare and include pneumothorax and hemothorax. Serious bleeding is seldom encountered. More commonly, inadvertent passage of the needle through the wall of the working channel of the flexible bronchoscope leads to expensive damage to the inner lining of the bronchoscope.\(^5\)

**Fluorescence Bronchoscopy**

Fluorescence bronchoscopy is a technique that detects early mucosal cancer by differentiating autofluorescence in normal and abnormal mucosa. When the normal bronchial mucosa is illuminated via the bronchoscope, a higher fluorescence is observed. Mucosal containing abnormal or malignant cells produces decreased autofluorescence. This phenomenon is used to detect mucosal changes suggestive of either premalignant or malignant lesions in the airway mucosa. Mucosal changes observed by routine (white-light) bronchoscopy can be compared with those observed via green-light bronchoscopy. Early reports show that this technique, when used as an adjunct to standard bronchoscopy, may enhance the ability to localize small neoplastic lesions, especially intraepithelial lesions.\(^9,10\)

**Bronchoscopic Ultrasound**

Clinical application of bronchoscopic ultrasound examination of the tracheobronchial tree is still in the investigational stage. The major advantage of this technique is the ability to visualize, via ultrasound, the extra-airway structures that cannot be seen through the bronchoscope.\(^11,12\) The major technical problem is the inability to consistently provide the coupling of the ultrasound probe to the bronchial wall to generate meaningful images of the extrabronchial structures. To overcome this, flexible bronchoscopes are being fitted with water-inflatable balloons. This will permit constant 360-degree contact between the wall of the airway and the ultrasound probe. Preliminary studies have shown the ability to identify mediastinal structures including lymph nodes, great vessels, and esophagus (Fig 1). The identification of lymph nodes and their relation to airways may help improve diagnostic techniques such as BNA for the diagnosis and staging of thoracic tumors.\(^13,14\) The simultaneous use of ultrasound-

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**Figure 1.** Bronchoscopic ultrasound image of the trachea (TR) at the level of the aortic arch (AOA) shows enlarged paratracheal lymph nodes (LN). An additional smaller lymph node (ln) is seen anterior to the trachea and posteriorly, esophagus (ES) and vertebral column (VC) are seen. Courtesy of Heinrich D. Becker, MD, FCCP.
guided BNA is desirable, but currently the technology is not available for clinical application.

**Virtual Bronchoscopy**

Virtual bronchoscopy does not involve bronchoscopy or insertion of any instrument into the airways. Images similar to those obtained with true bronchoscopy are created from the data accrued from CT of the chest.\textsuperscript{15–18} Three-dimensional reconstruction of the tracheobronchial anatomy provides better understanding of the relation of the airways to the other intrathoracic organs and structures. Obviously, the main advantage of virtual bronchoscopy is the ability to visualize the endobronchial anatomy without actually performing bronchoscopy. The major disadvantage is its inability to differentiate between malignant and benign lesions. Irrespective of the information gathered from virtual bronchoscopy, standard bronchoscopy or other procedures will be required to obtain tissue samples for histologic diagnosis. For now, virtual bronchoscopy remains an investigational tool.

**Table 1—Bronchoscopic Therapies*\textsuperscript{†}**

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Type of Lesion</th>
<th>Type of Bronchoscope</th>
<th>Rapidity of Positive Result</th>
<th>Repeatability of Therapy</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical debridement</td>
<td>E/Sm</td>
<td>R/F\textsuperscript{‡}†</td>
<td>++++</td>
<td>+++</td>
<td>Hmge, Lmge, fis</td>
</tr>
<tr>
<td>Laser</td>
<td>E</td>
<td>R/F\textsuperscript{‡}†</td>
<td>++++</td>
<td>+++</td>
<td>Hmge, Lmge, fis</td>
</tr>
<tr>
<td>Brachytherapy</td>
<td>E/Sm</td>
<td>F</td>
<td>+</td>
<td>+</td>
<td>Hmge, fis</td>
</tr>
<tr>
<td>Cryotherapy</td>
<td>E</td>
<td>R/F</td>
<td>++</td>
<td>+++</td>
<td>Minimal</td>
</tr>
<tr>
<td>Balloon dilatation</td>
<td>E/Sm/Ext</td>
<td>R/F\textsuperscript{‡}†</td>
<td>++++</td>
<td>+++</td>
<td>Minimal, fis</td>
</tr>
<tr>
<td>Photodynamic therapy</td>
<td>E</td>
<td>F</td>
<td>++</td>
<td>+++</td>
<td>Skin, PM</td>
</tr>
<tr>
<td>Electrocautery</td>
<td>E</td>
<td>R/F</td>
<td>++++</td>
<td>+++</td>
<td>Hmge</td>
</tr>
<tr>
<td>Stent</td>
<td>E/I/Ext</td>
<td>R/F\textsuperscript{‡}†</td>
<td>++++</td>
<td>+++</td>
<td>Mig, muc, inf, gran</td>
</tr>
</tbody>
</table>

*R = rigid bronchoscope; F = flexible bronchoscope; E = endoluminal lesion; Sm = submucosal lesion; Ext = extraluminal compression; I = intramural; ++++ = most rapid or repeatable; hmg = hemorrhage; fis = fistula; skin = photosensitivity reaction; PM = pseudomembrane formation; mig = migration of stent; inf = infection of airways; gran = granulation tissue growth; muc = mucous plugging. Adapted from Ramser and Beamis.\textsuperscript{51}†Rigid bronchoscope preferable.‡Dumon stent requires rigid bronchoscope; Wallstents and Gianturco stents require fluoroscopy.

**Therapeutic Bronchoscopy**

Therapeutic bronchoscopy accounts for more than half of all bronchoscopies. Therapeutic bronchoscopy to remove retained respiratory secretions, mucous plugs, and blood clots from the airways is common. In patients admitted to critical care units, up to 75% of bronchoscopies are for therapeutic purposes.\textsuperscript{19,20} Frequently, diagnostic and therapeutic bronchoscopies are performed simultaneously. The following discussion pertains to certain therapeutic procedures not routinely performed by all bronchoscopists.

**Laser Bronchoscopy**

Bronchoscopic treatment of airway malignancies is usually considered in patients with surgically unresectable lesions. The treatment is aimed at relieving obstructive symptoms rather than curing the neoplasm. Bronchoscopic techniques used to treat obstructing airway lesions, both benign and malignant, are listed in Table 1.

The majority of bronchoscopic laser therapies are performed using the Nd-YAG laser. Laser therapy can be used to treat both benign and malignant airway tumors that obstruct the major airways (Fig 2).\textsuperscript{21,22} Laser therapy also helps in preparing the airway for insertion of airway stents. Either rigid or flexible bronchoscopy can be used for application of laser energy, although the former accomplishes this more quickly. Immediate relief of airway occlusion and obstructive symptoms can be expected in > 90% of patients. Complications of laser therapy include severe hemorrhage, pneumothorax, and pneumomediastinum.\textsuperscript{23,24} Disadvantages of laser bronchoscopy include the requirement for special training and expensive equipment. Bronchoscopically visible tumors in the peripheral airway seldom require laser therapy unless relief of postobstructive pneumonia is necessary in a patient who cannot undergo surgical resection.

**Figure 2.** An example of Nd-YAG laser treatment of a benign tumor (fibrolipoma) in the right lower lobe bronchus. Left, A, tumor occluding the right lower bronchus; right middle lobe bronchus (RML) is open. Right, B, the star indicates laser burns where the stalk of the tumor was located. The lower lobe bronchi (RB 6–10) are now visible.
Brachytherapy

Brachytherapy is used to deliver radiation therapy from within the airway lumen to treat malignant tumors that obstruct the airways. This form of therapy is used to deliver radiation to palliate malignant airway lesions in patients who have already received maximum dose of external-beam radiation and cannot receive further external-beam radiation. The role of bronchoscopy is to place the brachytherapy catheter bearing the radioactive source into the obstructed airway, under direct vision. The most commonly used technique for endobronchial brachytherapy employs $^{192}$Ir. Both low-dose (< 2 Gy/h) and high-dose (> 10 Gy/h) brachytherapies are available. Overall, better than a 60% response can be expected following brachytherapy, and the relief of symptoms may last for weeks or months. Major complications include formation of fistulae between the airways and other thoracic structures in 6 to 8% of patients. Serious hemorrhage has been noted to occur more frequently in patients who receive high-dose radiation. The risk of massive hemoptysis increases dramatically when a fraction size of 15 Gy is used.

Dilatation of Airway Stenosis

The rigid bronchoscope itself can be used as a bougie to dilate malignant or benign airway stenosis. Repeated passage of rigid bronchoscopes of gradually increasing diameters can be used to dilate the trachea and mainstem bronchi. Balloon dilatation through either the flexible or rigid bronchoscope is best suited for stenoses that are short in length. Dilatation procedures are more effective if the airway stenosis is intrinsic rather than extrinsic. Most patients with chronic benign strictures require repeated dilatations. All types of dilatation procedures are effective if membranous or web-like lesions involving a very short length of the airways cause strictures and stenoses. Transmural strictures and stenoses involving long segments of the airway require either surgical or stent therapy.

Airway Prostheses (Stents)

Airway stents made of metal, silicone, or other materials are available in various shapes and sizes (Fig 3-5). Stents can be placed in the obstructed airways to provide relief of symptoms caused by malignant or benign airway disorders. Stent therapy is more effective in patients with tracheal or main bronchial diseases than in those with airway diseases that involve lobar and distal bronchi. Silicone stents seem better suited for both benign and malignant airway lesions, whereas covered metal stents may be useful in malignant airway stenosis. Use of the rigid bronchoscope is essential for the insertion, manipulation, and removal of silicone stents; metal stents can be inserted with the aid of flexible bronchoscopy and/or fluoroscopic guidance. Complications seen with silicone stents include migration of stent and inspissation of thick mucous within the stent lumen. Metallic stents seem to promote growth of granulation tissue, which makes it difficult to remove and replace the stent. Uncovered metallic stents should not be inserted in patients with malignant airway lesions because the growth of cancer through the wire mesh negates the benefits of stent placement.

Phototherapy

Compounds such as hematoporphyrin derivative fluoresce when exposed to the light of the proper wavelength. The resultant chemical reactions cause...
death of malignant cells through the production of toxic oxygen radicals. Patients with small (< 3 cm²), inoperable airway malignancies are most likely to benefit from this therapy. Within 24 to 48 h after IV administration of hematoporphyrin derivative, light of an appropriate wavelength is shined on the tumor for several minutes during bronchoscopy. Complete response lasting for > 12 months has been observed in 50% of patients. Complications from photodynamic therapy include sunburn involving skin exposed to bright light, hemoptysis, and expectoration of thick necrotic material. The latter, if not spontaneously expectorated, may lead to airway obstruction. Therapeutic bronchoscopy is sometimes necessary to remove the thick necrotic pseudomembrane.

Electrocautery

Bronchoscopic electrocautery employs alternating electrical current to produce coagulation and vaporization of endobronchial lesions. Argon plasma coagulator is also used to accomplish electrocautery therapy. Electrocautery probes are available for use with either flexible or rigid bronchoscopes. The indications for electrocautery are similar to those for cryotherapy. Immediate relief of symptoms caused by airway obstruction can be achieved with electrocautery in 55 to 75% of patients. The advantages of electrocautery include less expensive equipment (compared with lasers) and the ease of use through flexible or rigid bronchoscopes. Complications include endobronchial fire, hemorrhage, and inadvertent electrical shock to the operator or patient. Overall, electrocautery seems to be a good alternative to the more expensive laser therapy.

Cryotherapy

Bronchoscopic cryotherapy consists of cold-induced death of malignant cells by repeated cycles of cold application followed by thawing. Nitrous oxide or liquid nitrogen is most commonly used to produce temperatures of −80°C. Cryoprobes are available for use through rigid or flexible bronchoscopes. The indications for cryotherapy are same as those for other types of bronchoscopic therapies to treat airway neoplasms. Most importantly, the lesion must be accessible to the cryprobe through the bronchoscope. Smaller polypoid lesions visible in the distal airway are better suited for this type of therapy. Benign lesions have been treated with cryotherapy. The equipment is less expensive and easier to use than lasers. Subjective improvements have been observed in > 75% of patients with malignant airway lesions. Complications are few and minor. One disadvantage is the longer duration of therapy required because of the need for frequent freeze-thaw cycles. Repeat bronchoscopy is needed for continued therapy in many patients.

Bronchoscopic Resection of Airway Lesions

Large obstructing airway tumors are suitable for bronchoscopic resection. This is best accomplished with the rigid bronchoscope rather than the flexible instrument. This type of purely palliative therapy provides immediate relief of airway obstruction secondary to large neoplasms in the trachea or mainstem bronchi. Serious hemorrhage that may follow removal of tumor mass can be controlled by tamponading the bleeding point with the rigid bronchoscope itself. The flexible bronchoscope is ill-suited for this purpose because of the small working channel and its inability to remove large pieces of tumor and large volumes of blood.

Tracheobronchial Foreign Body

Rigid bronchoscopy is ideal for the extraction of aspirated tracheobronchial foreign bodies, especially in pediatric patients. In adults with airway foreign bodies, flexible bronchoscopy is effective in 61% of cases, whereas rigid bronchoscopy is successful in 98%. The flexible bronchoscope may be used to extract a foreign body that is impacted in airways too distal for access with the rigid bronchoscope. Newer ancillary equipment enable the flexible bronchoscope to extract large foreign bodies in the proximal airways.

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