The High Price of Bronchoscopy*  
Maintenance and Repair of the Flexible Fiberoptic Bronchoscope

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FFB = flexible fiberoptic bronchoscope; Nd:YAG laser = neodymium-yttrium:aluminum garnet laser;  
PDT = photodynamic therapy; TBAN = transbronchial aspiration needle; PVC = polyvinyl chloride; ETO venting cap = ethylene oxide venting cap

The practice of thoracic medicine was revolutionized by the advent of bronchoscopy. Killian1 was given credit for performing the first bronchoscopy in 1897, in an attempt to remove a foreign body. In the late 1960s, Shigeto Ikeda2 invented the flexible fiberoptic bronchoscope (FFB), initiating a new era in bronchoscopic evaluation. Fiberoptic bronchoscopy is now a simple, routine procedure commonly performed in the outpatient setting using local anesthesia by physicians without a surgical background.3,4 The current spectrum of diagnostic, therapeutic, and palliative capabilities of the FFB is vast and ranges from mere airway examination to palliative laser procedures.5-7 Design modifications and the development of accessories have paralleled today's increasing indications for its use. According to personal communications with various manufacturers of FFBs, the cost of the instrument has kept pace as well; several companies from around the world manufacture the instrument with a base price ranging from $8,000 to $12,000 (excluding the cost of the light source, forceps, etc).

The fiberoptic bronchoscope is composed of thousands of densely packed flexible glass fibers less than 10 µm in diameter. A set of high precision objective and ocular lenses are placed at the distal and proximal ends of this fiber bundle, respectively. These lenses are accurately aligned to provide adequate magnification of the endobronchial tree. The distal bending portion of the FFB is connected by metal wire to the control lever located at the proximal end. The distal end is covered with a thin rubber sheath to provide maximum flexibility while the remainder of the flexible insertion tube is covered by polyurethane. This delicate, sophisticated instrument may be easily damaged and the cost of even minor repairs may be extremely high. Adherence to proper maintenance procedures will maximize the life span of the instrument and minimize the repair costs.8 Key aspects of a proper care program include awareness of personnel of correct handling and manipulation of the FFB, appropriate use of accessory instruments, and strict adherence to the recommended procedures for cleaning, disinfecting, sterilization,9 storage, and shipping. The likelihood of damage to the FFB can also be reduced through proper patient instruction, sedation, positioning, and utilization of a bite block when appropriate.9,10

At our institution, we perform an average of 900 fiberoptic bronchoscopies each year. Besides the routine use of cytology brushes, double-lumen catheter brushes, and flexible forceps, 18- and 22-gauge transbronchial needle aspiration,11,12 catheter placement for endobronchial radiation therapy,13 photodynamic therapy (PDT),14 and neodymium yttrium aluminum garnet (Nd:YAG) laser photoresection15 are performed through the working channel of the FFB. During Nd:YAG laser photoresection, special instruments, such as flexible scissors, various types of snares, and Fogarty catheters are often used.15 All fiberoptic bronchoscopies are performed by one of six pulmonary special fellows under the direct supervision of one of the seven staff physicians. A bronchoscopy suite equipped with a fluoroscopy unit is available in the outpatient department as well as in the hospital. A total of ten FFBs are available for use. Three registered nurses assist both outpatient bronchoscopies and laser procedures. Eight specially trained respiratory therapists...
assist the bronchoscopist in the hospital setting. The following article describes our experience with specific types of damage to the FFB (Table 1) and recommendations on prevention of such problems.

**IMPROPER HANDLING**

The objective lens and the delicate quartz filaments of the FFB are particularly susceptible to trauma during routine use. Care must be taken not to allow the distal end of the instrument to strike a hard surface or this may fracture the objective lens. Forced angulation of the instrument along its flexible portion (Fig 1) or twisting the body of the scope (Fig 2) may damage its quartz filaments, resulting in the appearance of black spots in the field of vision and reducing the quality of the image (Fig 3). Excessive angulation most commonly occurs at the most proximal portion of the flexible insertion tube and can be minimized by maintaining an adequate distance between the patient's face and the control unit of the FFB. This can be achieved by adjusting the bronchoscopy table to the proper height or through use of a stepstool by the bronchoscopist when the procedure is performed with the patient in a supine position. If the patient is sitting in a chair, this distance can be easily adjusted by stepping backwards. Rotation of the body of the scope should be performed by flexing or extending the wrist.

![Figure 1](image1.jpg)

**Figure 1.** Forced or excessive angulation can lead to breakage of quartz filaments.

![Figure 2](image2.jpg)

**Figure 2.** Twisting of the body of the flexible fiberoptic bronchoscope can damage quartz filaments.

![Figure 3](image3.jpg)

**Figure 3.** Multiple damaged quartz fiber bundles appearing as black spots on the ocular lens. This fiber bundle damage was a result of a patient biting the flexible fiberoptic bronchoscope.

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**Table 1—Areas of Potential Damage to the Flexible Fiberoptic Bronchoscope**

<table>
<thead>
<tr>
<th>Area of Potential Damage</th>
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<tbody>
<tr>
<td>Improper handling</td>
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<tr>
<td>Procedural</td>
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<tr>
<td>Transbronchial needle aspiration</td>
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<tr>
<td>Nd-YAG laser photoresection</td>
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<tr>
<td>Electrosurgery</td>
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<td>Radiation</td>
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<td>Use of lubricants</td>
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<td>Patient related</td>
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<td>Cleaning and maintenance</td>
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<tr>
<td>Ethylene oxide gas sterilization</td>
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(Fig 4) rather than by twisting the flexible portion of the scope as shown in Figure 2, thereby limiting the torque applied to the instrument.

**PROCEDURAL**

The working channel of the FFB is lined by delicate plastic tubing. Although a thin tube allows maximal flexibility, the tubing is extremely vulnerable to trauma from the use of flexible endoscopic instruments. If this plastic tubing is perforated, fractured, or lacerated, liquids may seep into the flexible quartz bundles, fogging the field of vision and making further examination impossible (Fig 5). In our experience, this is a major drawback with the use of the immersible bronchoscope as its submersion into the cleaning solutions increases the likelihood that fluids will seep into the quartz filaments. The repair of damage to the plastic tubing requires dismantling the instrument to replace the tubing at a cost of nearly $3,000.

The proximal portion of the FFB is the most vulnerable area to such damage because flexible instruments impact on this portion of the tubing while negotiating the angulation. To prevent the damage, the proximal portion should be kept as straight as possible during insertion of any instrument through its working channel. Recently released FFBs have a separate distal port for instrument insertion. It is likely that the reduced angulation between the port and the working channel will limit the damage to the plastic tubing; however, we do not have adequate experience with such FFBs to comment at this stage.

**Transbronchial Needle Aspiration**

The transbronchial aspiration needle (TBAN) for cytology and histology specimens has significantly increased the diagnostic yield of fiberoptic bronchoscopy.\(^1\)\(^{-}\)\(^1\)\(^0\)\(^^{-}\)\(^1\)\(^8\)\(^-)\(^1\)\(^9\) However, if improperly used it may cause severe damage to the FFB.\(^1\)\(^9\) The majority of TBANs used to obtain cytology specimens have a re retractable metallic needle at the distal end, which is kept inside a protective catheter during its insertion through the working channel of FFB. Histology specimens may be

**Figure 4. Rotation of the body of the flexible fiberoptic bronchoscope should be performed by flexing (left) or extending (right) the wrist while avoiding twisting of the instrument as shown in Figure 2.**

**Figure 5. Perforation (arrow) of the inner channel of the flexible fiberoptic bronchoscope (FFB) by a transbronchial aspiration needle. Note kinking of the plastic channel, which occurred at the most proximal flexible portion of the FFB, as a result of repetitive excessive bending.**
obtained using an 18-gauge, 15-mm long, nonretractable metal needle, which is attached to the distal end of its plastic catheter. The nonretractable TBAN is potentially more traumatic because the working channel of the FFB is constantly exposed to its sharp end (oral communication, Dr. K. P. Wang, 1989). When a retractable TBAN is used, it should be ascertained that its beveled end is fully protected inside the metal hub, which is located at the distal end of its plastic catheter. However, the needle should not be pulled back proximal to the metal hub, where it may easily perforate the plastic catheter during its forward thrust and subsequently damage the channel of the FFB. The proximal, most flexible portion of the FFB should be kept as straight as possible and its distal tip should be kept in a neutral, forward viewing position during the insertion of the TBAN through the working channel. The metal needle should not be pushed out of its catheter unless the catheter is adequately visualized outside the FFB in the endobronchial tree. Once the specimen is obtained, the FFB should be optimally straightened for smooth withdrawal of the TBAN. Ideally, the "leak test" described in detail in the owner’s manual should be performed after each transbronchial needle aspiration to rule out perforation of the channel. This will permit early identification of damage to the FFB and flaws in one’s technique. In our opinion the TBAN should be used only by or under the supervision of an experienced bronchoscopist.

One should be aware of the diameter of the working channel of the FFB being used. Accessories with a diameter equal to or larger than that of the working channel of the FFB should not be forcefully inserted into the channel. Force should not be exerted to push rigid or semi-rigid accessories during their course through the working channel of the FFB. For example, an 18-gauge TBAN used to obtain histology specimens cannot be passed through the working channel of one bronchoscope (Olympus BF-1T20) because its 15-mm long metal needle will not negotiate the acute angle between the insertion port and the working channel of the FFB. Damaged endoscopic accessories such as forceps should be replaced rather than repaired due to the delicate nature of the precision parts involved. This will help prevent trauma to the FFB and provide greater patient safety as well.

Nd:YAG Laser Photoresection

Photoablation using the Nd:YAG laser has emerged as an important palliative therapy in the management of bronchogenic carcinoma and the benign unresectable endobronchial lesion. The procedure can be performed either through the rigid bronchoscope or the FFB. However, with the powerful capabilities of laser therapy comes an inherent danger of endobronchial ignition. The FFB is made up of combustible materials that are vulnerable to endobronchial ignition. Concomitant use of a highly combustible polyvinyl chloride (PVC) endotracheal tube, while performing Nd-YAG laser procedure through the FFB, further increases this risk. While use of the FFB to perform such procedures is not contraindicated, extreme care should be taken to avoid the possibility of endobronchial ignition. The laser beam should never be fired unless the tip of the laser fiber is adequately visualized in the endobronchial tree and is at least 5 mm away from the end of the FFB. Both the tip of the laser fiber and the FFB should be kept free of any carbon particles because they can ignite and start an endobronchial fire. Alcohol or alcohol-based solutions should not be used to clean the laser fiber tip to avoid the possibility of combustion. The concentration of supplemental oxygen should not exceed 40 percent. If the procedure is being performed through a PVC endotracheal tube, the maximum possible distance should be maintained between its tip and the treatment site. A low power density and a short pulse duration will minimize the chances of endobronchial ignition.

A coaxial flow of air or saline solution should be continuously maintained during the use of laser energy to keep the laser tip cool and clean, otherwise the heated metal tip of the noncontact laser fiber could damage the channel of the bronchoscope during its withdrawal (Fig 6). In our personal opinion, the safety of the bare laser fiber (ie, one without a protective plastic catheter and mechanism for coaxial gas or saline solution flow) has not been fully established and it should therefore be avoided. An endobronchial fire may destroy the FFB. It should be noted that manufacturers of the FFB have not included laser procedures as one of the indicated uses of the instrument and may not provide warranty repairs for laser-related damage to the instrument.

Electrosurgery

The role of electrosurgery performed via the flexible endoscope in the management of various gastrointestinal tract lesions is well established. In recent years there has been increasing interest in the application of this modality in the management of endobronchial lesions. However, unlike flexible endoscopes, FFBs are not electrically grounded. If the wire electrocautery loop inadvertently touches the tip of the FFB the current could ground through the FFB and the endoscopist, generating sparks at either end of the instrument. In the presence of a high concentration of oxygen this could start an endobronchial fire causing severe damage to the FFB. A firm understanding of the basic principles of electrosurgery, familiarization...
with the equipment and accessories being used, and maintaining low concentrations of inspired oxygen will decrease the risk of this type of damage. Because of its special design, bipolar cautery might be safer than wire loop cautery in this regard. 

Radiation

Fluoroscopy has added immensely to the procedure of fiberoptic bronchoscopy, especially while performing brushings, transbronchial biopsies, transbronchial needle aspiration of peripheral nodules and localized bronchography. Excessive exposure of the FFB to radiation may result in yellowish discoloration and darkening of both the fiber bundles and the visual image. The exact dose of radiation at which damage occurs is unknown and therefore unnecessary radiation should be limited. Specifically, the FFB should not be stored in areas where fluoroscopy is performed or roentgenograms are routinely taken.

Use of Lubricants

A water-soluble lubricant should be used to lubricate the instrument and petroleum-based products should be avoided. The latter may cause premature wear with stretching and deterioration of the rubber sheath of the FFB.

Patient-Related Damage

Patient cooperation is essential to minimize the possibility of injury to the FFB. Although the examination can be performed facing the sitting patient, the supine position provides greater patient relaxation and lessens the likelihood of a vaso-vagal attack, which might lead to grabbing or pulling the fiberscope by the patient. While the most common method of insertion is the transnasal approach, it may be necessary to use the transoral approach or to perform the procedure through the endotracheal tube. A mouthpiece (bite guard) must be used during the latter two routes of approach. The mouthpiece should consist of a firm plastic material and be securely fastened to the patient's face. Failure to employ a bite block may result in accidental compression of the FFB by the patient's teeth with damage to the fiber bundles (Figs 3 and 7). In addition, when performing fiberoptic bronchoscopy through the endotracheal tube, proper lubrication and appropriate matching of scope size to tube size should be carried out to prevent tearing of the rubber covering over the distal portion of the FFB.

Cleaning and Maintenance

Strict adherence to the recommended procedures for cleaning, disinfection, and sterilization must be employed as these instruments have limited tolerance for trauma, heat, and chemical agents. Care must be taken to immerse only appropriate parts in the cleaning solution. The proximal control unit, eye piece, or light connector of nonsubmersible FFBs should never be immersed in the cleaning solutions. For disinfection, use of the recommended agents for the suggested contact time will decrease the premature aging of components. Alkaline glutaraldehyde products (such as Cidex, Sonacide, Glutarex, and Sporicidin) are commonly used agents. When povidone-iodine (Betadine) is used the distal viewing tip should be thoroughly wiped to prevent yellowish discoloration of the viewing lens. The FFB should not be autoclaved or placed in boiling water.

Submersible FFBs are completely sealed to make them air tight. Pressure differences developing between the interior and the exterior of the body of the FFB can lead to severe damage. Whenever ethylene oxide (ETO) gas sterilization of the equipment becomes necessary, the ETO venting cap, which permits equalization of pressure changes between the interior and exterior of the FFB, must be installed (P. C. Curtis, written communication, 1988). Failure to use the venting cap correctly may result in rupture of the bending rubber when a vacuum is created during the sterilization procedure (Fig 8). Following gas sterilization the ETO cap must be removed to reseal the FFB to ensure water-tightness. During gas sterilization maximally tolerated conditions are as follows: temperature of 55°C (131°F), pressure of 1.7 kg/cm² (24 PSI), time of four hours, humidity of 50 percent, and gas concentration of 10 percent.

The FFB can be safely stored in a vertical position.
with the insertion tube as straight as possible and the angulation control lock released. The storage location should be clean and dry with a constant temperature and good ventilation. The original carrying case should be used for shipping only. For storing, the insertion tube should be coiled loosely with care taken not to damage the instrument during closure of the case lid. The ETO venting cap must be put on during long-distance transportation of the instrument.

**Financial Impact of Fiberoptic Damage**

To evaluate cost factors for a busy bronchoscopy service, we have reviewed our bronchoscopy repair records specifically for the rate of occurrence of preventable and unpreventable repairs over a 4½-year period (January 1985 through June 1989) (Table 2). Preventable repairs were defined as repairs that involved some type of human error. Unpreventable repairs were classified as mechanical failure alone. Approximately $20,000 per year (total $89,863.11) was spent over this period to repair damaged FFBs. We do appreciate that the number of endoscopic examinations, the type of endobronchial procedures (laser, TBNA, etc.), and the training of our pulmonary fellows impacted on our repair cost. However, review disclosed that approximately 87 percent of our repairs were preventable, including perforation of the working channel, damage related to laser therapy, accidentally pinching the body of the FFB while closing the carrying case lid, or the patient biting on the fiberoptic bronchoscope. Only 13 percent of repairs, such as a frozen distal tip (distal tip fixed in one position that could not be maneuvered manually or by using proximal controls) or impaired angle control mechanism were considered unpreventable.

We examined the various manufacturers’ instruction manuals and found that they contained explicit directions for prevention of several such complications. However, according to our own survey, only 11 percent of personnel involved with the procedure of FFB will familiarize themselves with the instruction manual. We believe that this manual is an underused resource for the education and training of all staff. It should be readily available for reference and recommended at the beginning of training for fiberoptic bronchoscopy. In addition, information may need to be updated as new techniques are developed with procedures that differ from those described in the original manual.

We speculate that the costs of a bronchoscopy service may be significantly reduced by instituting a proper care program. With emphasis on cost containment, we wonder if extended product warranties, service contracts, or insurance contracts might soon be an option.

In conclusion, cognizance of the indications and contraindications for the performance of FFB, and the proper use and care of the instrument, will maximize the life span of the instrument and minimize the associated repair costs.

**Table 2—Summary of Flexible Fiberoptic Bronchoscope (FFB) Repair Cost at The Cleveland Clinic Foundation, January 1985 to June 1989**

<table>
<thead>
<tr>
<th>Types of Damage</th>
<th>Average Cost per Repair</th>
<th>Frequency</th>
<th>Type of Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impaired angle control</td>
<td>$1,632</td>
<td>5</td>
<td>Unpreventable</td>
</tr>
<tr>
<td>Frozen distal tip†</td>
<td>$2,300</td>
<td>1</td>
<td>Unpreventable</td>
</tr>
<tr>
<td>Damaged inner channel by TBAN</td>
<td>$2,720</td>
<td></td>
<td>Unpreventable</td>
</tr>
<tr>
<td>Damaged inner channel by Nd-YAG laser</td>
<td>$2,720</td>
<td></td>
<td>Unpreventable</td>
</tr>
<tr>
<td>Damaged inner channel by Flexible forceps</td>
<td>$2,720</td>
<td></td>
<td>Unpreventable</td>
</tr>
<tr>
<td>Damaged inner channel by FFB bitten by the patient</td>
<td>$2,720</td>
<td>1</td>
<td>Preventable</td>
</tr>
<tr>
<td>Damaged inner channel by Brocken control arm wire</td>
<td>$1,447</td>
<td>1</td>
<td>Unpreventable</td>
</tr>
<tr>
<td>Damaged inner channel by Worn external sheath</td>
<td>$74.50</td>
<td>2</td>
<td>Unpreventable</td>
</tr>
<tr>
<td>Damage by carrying case lid†</td>
<td>$26.50</td>
<td>4</td>
<td>. . .</td>
</tr>
</tbody>
</table>

*Total number of repairs: 42; total repair cost: $89,863.11; total number of bronchoscopies (including photodynamic therapy): 3,828; total number of Nd-YAG laser photoresections: 166; and preventable repair cost: 87 percent. TBAN = transbronchial aspiration needle; ETO = ethylene oxide.
†See text.

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