Development of an Ultrathin Fiberscope With a Built-in Channel for Bronchoscopy in Infants*

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Flexible fiberoptic bronchoscopy (FFB) is of great importance for diagnostic and therapeutic purposes in pediatric respiratory management. However, lack of a built-in channel in commercially available ultrathin fibrescopes has limited its usefulness in neonates and infants. Bronchoscopic procedures, including suctioning, BAL, bronchography, and selective drug injection have instead been performed by temporary extubation followed by mask ventilation. However, such techniques are not suitable for repeated FFB and are open to considerable risks, especially in critically ill patients. In this context, we developed a directable ultrathin fibrescope with an external diameter of 2.7 mm and a 0.8-mm internal diameter built-in channel. This prototype fibrescope, the XPF27, is useful during spontaneous ventilation and can be inserted through a 3.5-mm or larger endotracheal tube. The XPF27 was utilized for 55 FFB procedures and allowed suctioning, BAL, bronchial toileting, and bronchography in 16 critically ill children without complications. We conclude that XPF27 is useful for pediatric FFB despite its limited flexibility, visual field, and resolution.

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Key words: atelectasis; bronchial suctioning; bronchoalveolar lavage; children; fiberoptic bronchoscopy; mechanical ventilation; suction channel; ultrathin fibrescope

Abbreviations: ED=external diameter; FFB=fiberoptic bronchoscopy; ID=internal diameter

Flexible fiberoptic bronchoscopy (FFB) is one of the most important modalities for diagnostic and therapeutic purposes in intensive respiratory care, for children and for adults.1-8 FFB in an ICU is characterized by the following factors: (1) as patients are in a critical condition and most of them are ventilated, ventilatory assistance during FFB is frequently required; (2) FFB is performed for both diagnostic and therapeutic reasons, in contrast with that for outpatients in whom bronchoscopy is performed mainly to make diagnoses; (3) repeated FFB is often required.

The largest obstacle to FFB in small children is the lack of appropriate bronchosopes. Most bronchoscopic procedures, including suctioning, biopsy, brushing, drug injection, and BAL can be performed for children for whom a 3.6-mm external diameter (ED) bronchoscope is appropriate. However, a conventional fibrescope with a built-in channel is sometimes inappropriate for neonates and infants, and is not available in children who are intubated with 4.0-mm internal diameter (ID) or smaller tracheal tubes. It should be emphasized that these are the patients most susceptible to respiratory complications, and so are most likely to require FFB. When FFB is required by these patients, temporary extubation followed by ventilatory assistance with a laryngeal mask is usually performed during FFB.9 However, this procedure does not cope with vomiting, airway bleeding, and laryngospasm. A rigid bronchoscope is also available for these patients, but its view is limited to the trachea and the main bronchi, and repeated bronchoscopy with a rigid bronchoscope is not desirable due to repeated uses of general anesthesia.

To enable bronchoscopic procedures requiring a channel in patients for whom conventional fibrescopes are not appropriate, we previously developed the modified PF22, which has an external channel attached to the shaft of the PF22, a conventional ultrathin fibrescope (Olympus Optical Co Ltd; Tokyo).10 To date, 43 FFBs have been performed without complications using the modified PF22 for 13 infants intubated with a 3.5- or 4.0-mm ID tracheal tube. However, there are still some problems with the modified PF22: (1) due to its external channel, the flexibility and handling of the modified PF22 are

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somewhat reduced compared to the original PF22; and (2) to prevent dislocation of the dressing tape that fixes the external channel to the shaft of the PF22, rewrapping with a new tape is required before each bronchoscopy.

For better handling and safety, we recently developed the XPF27, another ultrathin fibroscope with a built-in channel, and utilized it in the critical respiratory care of ventilated infants.

Materials and Methods

XPF27

The XPF27 is a prototype fibroscope produced by the manufacturer (Olympus Optical Co Ltd; Tokyo) at our request. Specifications required for the XPF27 were as follows: (1) it must be thin enough to permit simultaneous ventilation even when it is inserted into a 3.5-mm ID tracheal tube; (2) it must have a built-in channel large enough for suctioning, drug injection, and BAL; and (3) its flexibility and handling must be equivalent to conventional ultrathin fiberscopes.

Table 1—Fiberscopes and Ultrathin Fiberscopes

<table>
<thead>
<tr>
<th></th>
<th>ED, mm</th>
<th>ID of the Channel, mm</th>
<th>Flexibility, Up/Down</th>
<th>Visual Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) BF3C30</td>
<td>3.6</td>
<td>1.2</td>
<td>180°/130°</td>
<td>120°</td>
</tr>
<tr>
<td>(2) PF22</td>
<td>2.2</td>
<td>None</td>
<td>120°/120°</td>
<td>75°</td>
</tr>
<tr>
<td>(3) m-PF22</td>
<td>2.2+1.15</td>
<td>0.69</td>
<td>90°/75°</td>
<td>75°</td>
</tr>
<tr>
<td>(4) XPF27</td>
<td>2.7</td>
<td>0.50</td>
<td>120°/60°</td>
<td>55°</td>
</tr>
</tbody>
</table>

The external appearance and the sealing material of the shaft of the XPF27 are the same as those of conventional fiberscopes (Fig 1). The optic fibers are made of quartz glass; the XPF27 contains approximately 30% fewer fibers than the BF3C30 (Olympus). The ED of the XPF27 is 2.6 mm at the tip and 2.7 mm along the shaft. Its total length is 760 mm, and the effective length is 560 mm. The angle of the visual field is 55° and the resolution is approximately 70% of the resolution of the BF3C30 (Olympus). The tip can be curved 120° upward and 60° downward. The XPF27 has a 0.8-mm ID built-in channel. A comparison of the specifications of the XPF27, the modified PF22, and conventional bronchoscopes is shown in Table 1.

Patients and Anesthesia

The XPF27 was used for patients who meet the following criteria: (1) The BF3C30 was not appropriate for the patient due to the size of their airway or the endotracheal tube, and (2) the procedure required the use of a channel in the bronchoscope. Therefore, the PF22 was used instead of the XPF27 for patients in whom only visualization of the airway was required.

When the XPF27 was used in intubated patients, manual ventilation with a bag was performed through a swivel Y-connector (Bocai suction-safe SM1-1002; Sontek Medical Inc; Hingham, Mass) during FFB. A minimal dose of IV midazolam for sedation and 4% lidocaine for topical anesthesia was given, if required.

Measurement of Airflow Resistance

The increase in airflow resistance induced by the insertion of the bronchoscope into the trachea was assessed using a model reported by Wood and Fink. Airway resistance was measured using 3.5- and 4.5-mm ID tracheal tubes (TR-G035 and TR-G045; Terumo; Tokyo) at an airflow rate of 0.2 L/s.
### Table 2—Demographic Data of 16 Patients

<table>
<thead>
<tr>
<th>Data</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mo</td>
<td>0-46 (median value=11)</td>
</tr>
<tr>
<td>Sex, male/female</td>
<td>8/8</td>
</tr>
<tr>
<td>Body weight, kg</td>
<td>2.7-11.8 (median value=6.75)</td>
</tr>
<tr>
<td>Backgrounds, No.</td>
<td></td>
</tr>
<tr>
<td>Liver transplantation</td>
<td>9</td>
</tr>
<tr>
<td>Cardiac surgery</td>
<td>4</td>
</tr>
<tr>
<td>Congenital airway anomaly</td>
<td>2</td>
</tr>
<tr>
<td>Pneumomediastinum</td>
<td>1</td>
</tr>
</tbody>
</table>

### RESULTS

Sixteen patients underwent 55 FFBs performed with the XPF27. Characteristics of the patients are shown in Table 2. Five FFBs were performed in 2 patients with congenital airway anomaly (ages 9 days and 3 months) while the patients were spontaneously breathing, and 50 FFBs were performed in 16 patients during mechanical ventilation through tracheal tubes with 3.5- or 4.0-mm IDs. Indications for FFB were pneumonia (n=8), physiotherapy-resistant atelectasis (n=7), tracheobronchomalacia (n=4), massive airway bleeding (n=2), pulmonary edema (n=2), and pneumomediastinum (n=1). All the patients required bronchoscopic suctioning. BAL was performed in nine patients who had possible pneumonia, including a patient who was receiving extracorporeal membrane oxygenation. Microbiologic examination of specimens obtained from BALs were positive for pathogenic organisms in eight cases (Pseudomonas aeruginosa: n=4; Enterococcus cloacae: n=2; methicillin-resistant Staphylococcus aureus: n=2; and Candida albicans: n=1), and negative in the case of pulmonary edema. The two patients with airway bleeding required epinephrine injections into the affected bronchi, but did not respond to bronchoscopic therapies and died due to progressive hepatic failure. FFB for atelectasis resulted in a full reexpansion of the collapsed lungs in five patients (Fig 2) and partial or no response in two.

Severe hypoxia (oxygen saturation by pulse oximeter <80%) and bradycardia occurred during bronchoscopic suctioning in a patient with airway bleeding, who recovered immediately after cessation of FFB and...
ventilation with a bag. No other serious complications relating to FFB were experienced.

Figure 3 shows the airway resistance results. Figures indicate resistance to airflow through each size of tracheal tube (Fig 3, top: 3.5-mm ID; Fig 3, bottom: 4.5-mm ID) with fiberscopes passed through them. Increased resistance induced by the XPF27 was slightly higher than that of the original PF22, but significantly lower than that of the BF3C30.

**Discussion**

The XPF27 has been developed for better handling and safety over the modified PF22. Specifications for the XPF27 were as follows: (1) it must be thin enough to permit simultaneous ventilation even when it is inserted into a 3.5-mm ID tracheal tube; (2) it must have a built-in channel large enough for suctioning, drug injection, and BAL; and (3) its flexibility and handling must be equivalent to conventional ultrathin fiberscopes.

The advantage of the XPF27 is that to our knowledge, it is the only ultrathin fiberscope with a directable tip and a built-in channel. The XPF27 enables airway cleaning, which we believe to be an essential part of the pediatric respiratory care. The suction power of the XPF27 is stronger than the modified PF22. In all cases, airway cleaning was successfully performed; however, its 0.8-mm ID channel was sometimes plugged with dense airway mucus and required flushing with saline solution. BAL (n=8) and selective drug injection (n=2) were smoothly performed in our patients. Furthermore, a prototype brush (BC-2.7T; Olympus) is also available, although we have not performed airway brushing in the present patients. The airflow resistance data reveal that the increase of airway resistance induced by the XPF27 is almost equivalent to that by the original PF22, and that the XPF27 permits safe simultaneous ventilation when the patient is intubated with 3.5-mm ID or larger tracheal tube.

There still remain some disadvantages to the XPF27: (1) its flexibility is limited due to the material of the optic fibers; insertion of the XPF27 into the bilateral upper bronchi was successful in all cases, but was sometimes difficult; (2) the visual field and the resolution of the XPF27 are inferior to the BF3C30. However, suctioning through the XPF27’s built-in channel results in better practical visualization than that provided by the PF22.

The XPF27, in 55 FFBs, proved a utility that conventional bronchoscopes fail to offer. We conclude that the XPF27 is a safe and useful instrument for intensive respiratory care in neonates and infants.

**References**