Advances and Usefulness of Ultra-thin Bronchofiberscopes

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Abstract. We developed new types of ultra-thin bronchofiberscopes, BF-2.2T and BF-2.7T to observe and photograph lesions of 2mm or less in bronchioli. BF-2.2T and BF-2.7T can be bent to achieve a vertical range of 120 degrees. BF-2.7T has an additional channel for biopsy and can be used to collect cells. The ultra-thin bronchofiberscopes allowed us to observe all cases of peripheral pulmonary carcinoma and to collect cells. We are now studying IL-6, IL-8 and mRNA in cell specimens collected from patients with lung cancer using the ultra-thin bronchofiberscopes. The development of these ultra-thin bronchofiberscopes have allowed remarkable advances in clinical practice and research because these endoscopes allow bronchioles to be observed directly and to collect bronchial epithelial cells from necessary areas for subsequent incubation and cytological assessment. (Keio J Med 45 (4): 296–300, December 1996)

Key words: ultra-thin bronchofiberscope, peripheral airways, bronchiole, classification of endoscopic features of bronchioles

Introduction

During the 14th World Congress of the Chest in 1982,1 we first made an ultra-thin bronchofiberscope BF-1.8T which we had developed for use in a pilot study to allow public us to observe the interior of the peripheral airway. The BF-1.8T2 had an outer diameter of 1.8 mm. It was composed of about 3000 glass fibers. It was designed to allow direct observation of 2–30 mm sized objects within a range of 75 degrees. The effective length of this bronchofiberscope was 1150 mm, and its total length was 1350 mm. It had no channel for biopsy. Its tip did not bend vertically or horizontally. Later, this bronchoscope was extensively modified. The latest version has an additional channel for biopsy, and its top can be bent for a vertical range of 120 degrees.

This paper outlines the latest ultra-thin bronchofiberscope3,4 and describes its utility.

Significance of Bronchiole Observation in the Diagnosis and Management of Respiratory Disease

Evaluation of the bronchioles is important when diagnosing peripheral type pulmonary carcinoma. Bronchiolar evaluation is also important for the diagnosis and pathophysiological study of inflammatory disease of the respiratory system, because the peripheral airway (including the bronchioles) can be injured by diverse factors that include smoking, air pollution, viral infection, pneumoconiosis and granuloma.

Investigators have recently been paying close attention to the role of the epithelial cells of the airway in the onset of various airway diseases such as bronchial asthma and chronic bronchitis.5,6 Infiltration of various inflammatory cells in the airway epithelium has been observed in patients with injured airway epithelia, and a significant correlation has been found between the degree of inflammatory cell infiltration and the severity of disease. It has therefore been estimated that injury of the airway epithelium is closely related to airway disease.

The state of the peripheral airway also seems to be related to airway disease. In recent years, attempts have been made to assess pathologic bronchioles or to make early diagnosis of bronchiolar lesions. Following the introduction of high-resolution CT with improved imaging capacities, it is now possible to observe the...
respiratory organs in detail, even to the level of pulmonary lobules. Findings from such observations are compared with pathological findings to analyze various lung diseases (especially the peripheral structure of lungs). Changes in lung structure which can be caused by individual bronchiolar lesions can now be estimated to some extent, but there are still many open questions.

**History of Bronchoscopes**

The history of bronchofiberscopy dates back to 1895, when Killian used a laryngoscope. Subsequently, Kirstein (1897) used an esophagoscope to observe the bronchi. Killian later manufactured the first bronchoscope. Coolidge (1898) used a bronchofiberscope to remove a cannula which had accidentally slipped into the right bronchial trunk. Taking a hint from the esophagoscope with an attached illuminator, devised by Einhorn (1902), Jackson (1905) devised a bronchofiberscope by modifying this esophagoscope. This bronchofiberscope served as a base for subsequent modifications into other types of bronchofiberscopes. A series of bronchofiberscopes have been devised by modifying Jackson's bronchofiberscope and are called Jackson type bronchofiberscopes.

Jackson's bronchofiberscope can observe only a narrow range and its visual field is not bright enough. For this reason, it was difficult to adequately assess lesions using this bronchofiberscope. To resolve these problems, Morlock (1932) developed a telescope, which was an optimal tube inserted into a bronchofiberscope to magnify bronchoscopic images.

Anterooblique or lateral endoscopes, with a small bulb for illumination attached to their tip, were developed and used. Subsequently, Brunbaker and Hollinger et al. (1941) succeeded in taking color pictures of bronchi, modified a light source generator using crystal rods, and developed high-illumiance light generators using xenon. Katuki and Horie (1961) devised a modified form of telescope which was composed of a bundle of about 10,000, 20-micron, glass fibers (to serve as light conductors) and central coated lenses. The range of observation with telescopes was widened by this invention. Ikeda (1966) developed a flexible bronchofiberscope to take the place of conventional rigid bronchofiberscopes. As a result, it became possible to observe sub-subsegmental bronchi (the fourth group of bronchi).

Following recent sharp advances in electronic technology, CCDs (charged coupled device) which are smaller in size, easier manipulation and improved color reproducibility have been developed and have been increasingly used for video scopes. Ultra-thin bronchofiberscopes have also been gradually improved after the development of BF-1.8T. Current ultra-thin bronchofiberscopes have a high durability, are easier to manipulate and have better capacities, as compared to conventional ones.

Bronchosopes currently used usually have a tip outer diameter of 5.9 mm. They are inserted from the mouth into the trachea to observe bronchi. Since the diameter of the trachea is 15–22 mm in males and 13–18 mm in females, the bronchofiberscopes with a tip diameter of 5.9 mm cannot observe bronchi smaller than the subsegmental bronchi (the third group of bronchi). On the other hand, ultra-thin bronchofiberscopes can observe even bronchioles with an outer diameter of less than 2 mm.

**Specifications and Capacities of Ultra-thin Bronchofiberscopes (Table 1)**

<table>
<thead>
<tr>
<th>Specifications</th>
<th>BF-2.2T</th>
<th>BF-2.7T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Length</td>
<td>1400 mm</td>
<td>1400 mm</td>
</tr>
<tr>
<td>Effective Length</td>
<td>1150 mm</td>
<td>1200 mm</td>
</tr>
<tr>
<td>Apical Part Diameter</td>
<td>2.2 mm</td>
<td>2.7 mm</td>
</tr>
<tr>
<td>Angle Deflection</td>
<td>up 120° down 120°</td>
<td>up 120° down 120°</td>
</tr>
<tr>
<td>Angle of Visual Field</td>
<td>75°</td>
<td>55°</td>
</tr>
<tr>
<td>Depth of Focus</td>
<td>3–50 mm</td>
<td>1–30 mm</td>
</tr>
<tr>
<td>Channel Size Diameter</td>
<td>none</td>
<td>0.8 mm</td>
</tr>
</tbody>
</table>

**Application**

The patient is not allowed to ingest any food during a
period of about 5 hours before the examination. Atropine sulfate, 0.5 mg, is injected intramuscularly 10–15 minutes before the insertion of a bronchofiberscope. The patient then inhales 2 ml of 2% Xylocaine using a nebulizer. The inferior larynx is then anesthetized with 2% Xylocaine until the gag reflex disappears. At the same time, 2 ml of 2% Xylocaine is injected into the trachea through a laryngeal injector. Before bronchoscopy, chest X-ray and CT are taken to determine the area to be observed with a bronchofiberscope. Bronchoscopy commences by oral insertion of a bronchofiberscope with an additional channel for biopsy (diameter over 2.8 mm), i.e. BF type XT20 or BF type 1T30. The bronchofiberscope is inserted into the trachea until it wedges in the target bronchus. Under fluoroscopic guide, an ultra-thin bronchofiberscope is then inserted through the biopsy channel to observe the target area. Bronchi with smaller diameters are observed, making use of respiration-related changes in the inner diameter of bronchioles. If observation is hampered by excessive secretions, the patient is instructed to inhale several times or the bronchofiberscope is pulled slightly and its tip is shaken slightly to erase secretions from the visual field. To avoid the contact of the bronchofiberscope tip with bronchioles, the bronchofiberscope is inserted to a point 2–3 bifurcations proximal to the area for observation with an ultra-thin bronchofiberscope.

What Can Be Observed with Field of View of An Ultra-thin Bronchofiberscope?16 (Fig 1)

The ultra-thin bronchofiberscopes are fit for observing bronchioles with an outer diameter smaller than 3 mm. Features of the relatively thick bronchi, observed with ultra-thin bronchofiberscopes, have been summarized by the Japan Lung Cancer Society into the classification of bronchoscopic findings. Endoscopic findings of bronchioles have been prepared by the authors, based on their observation of clinical cases of peripheral airway lesions and healthy volunteers (521 subjects in total) and referring to the classification of bronchoscopic findings prepared by the bronchoscopic findings classification committee of the Japan Lung Cancer Society.

Classification of Endoscopic Features of Bronchioles (Table 2)

Features of the bronchiolar wall observed with endoscopes include reddening, pallor, loss of luster, edema, overswellling of blood vessels, irregular mucosa and polyp-like appearance. Endoscopically observed morphological abnormalities of the bronchiolar lumen include stenosis, obstruction and dilatation. Abnormal substances endoscopically detected in the bronchiolar lumen include secretions and pigments.

The classification of endoscopic features of the central airway, prepared by the Japan Lung Cancer Society, include a larger number of features than the classification of endoscopic features of bronchioles. Usually, endoscopic features of bronchioles differ considerably from the endoscopic features of the central airway even in the same patient, when accompanying findings are also taken into account. Bronchiolar diseases often show specific endoscopic features different from the features of the
Endoscopic Features of Bronchioles (Fig 2, 3, 4)

The endoscopic finding of reddening corresponds to the pathological findings of neutrophil infiltration and vascular changes observed in the bronchial wall. Pallor and loss of luster are caused by disturbed microcirculation of the bronchial mucosa. Pigmentation is attributable to carbon powder deposition. This is seen in smokers, patients with pneumoconiosis and patients exposed to air pollution. The color of bronchioles is black, blue or green. Bronchiolar obstruction is caused by secretions, inflammatory changes or tumors. Bronchiolar stenosis is caused by inflammation, tumors or functional changes. Bronchiolar dilatation can be divided into two types; a type with marked dilatation but little changes of the bronchial mucosa, a type showing marked bronchial dilatation and marked changes in the bronchial mucosa. Vascular overextension can be divided into two types; a type with vessels gathering in the bronchial mucosa, and a type without vessels gathering in the bronchial mucosa. Edema of the bronchial mucosa is visible as mucosal swelling. Endoscopes are difficult to insert to the periphery of bronchioles because bifurcations with wide angles are present in this area.

Endoscopic features of the bronchioles in patients with peripheral type pulmonary carcinoma can be divided into three types; 1) the submucosal obstruction type (lesions located below the mucosa of the airway lumen),
2) the exposed type (lesions exposed on the lumen), and 3) the nodal type (polyp-like lesions within the airway lumen).

Ultra-thin Bronchofiberscope and Cytology

We attempted to collect cells from the peripheral airway, while directly observing this area with a BF-2.7T. The subjects were 10 males and 7 females, with a mean age of 55.58 ± 2.06 years. Of these 17 subjects, 6 were smokers, 5 were ex-smokers and 6 were non-smokers. The underlying disease was peripheral type pulmonary carcinoma in 5 cases (adenocarcinoma in 4 and squamous cell carcinoma in 1), chronic bronchitis in 3, interstitial pneumonia in 2, bronchial asthma in 2, bronchopneumonia in 2, pulmonary tuberculosis in 1, and pulmonary sarcoidosis in 1. The number of cells collected from the airway epithelium averaged 3.58 ± 2.76 × 10⁴ (P < 0.05). The cell survival rate was 33.13 ± 3.61%. When the cell specimens were incubated, 28.5% of them became confluent, without being contaminated by microorganisms. The ultra-thin bronchofiberscope allowed us to observe all cases of peripheral type pulmonary carcinoma and to collect cancer cells. We are now studying interleukin-6, interleukin-8 and mRNA in cell specimens collected from patients with lung cancer using the ultra-thin bronchofiberscope.

The development of this ultra-thin bronchofiberscope has allowed remarkable advances in clinical practice and research because this endoscope allows bronchioles to be observed directly and to collect bronchial epithelial cells from necessary areas for subsequent incubation and cytological assessment.

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