Thin Bronchoscope for Evaluating Stenotic Airways during Stenting Procedures

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Abstract

Background: Flexible bronchoscopy can play an important role in the evaluation of an airway lumen during therapeutic bronchoscopic procedures. Despite its potential usefulness, however, evaluation with a standard-sized bronchoscope, which cannot pass completely through a severely stenosed airway, is often unsatisfactory. Objectives: This study aimed to evaluate the usefulness of prototype thin bronchoscopes for assessing stenotic airways during stenting procedures. Methods: Forty-six patients with central airway stenosis requiring stent implantation were enrolled in this prospective study. After inserting a rigid bronchoscope under general anesthesia, a flexible bronchoscopic evaluation using a 5.9- or 6.0-mm standard bronchoscope was performed, followed by evaluation using a prototype 3.4- or 3.5-mm thin bronchoscope for airways beyond the site of stenosis, which could not be visualized by the standard bronchoscope. Results: A standard bronchoscope could not pass through the stenotic airway in 15 of 46 patients (33%). On univariate analysis, the grade of stenosis (p < 0.001), the presence or absence of atelectasis (p = 0.04) and the presence or absence of viscous secretions (p = 0.02) were related to the rate of successful passage by a standard bronchoscope. On multivariate analysis, only the grade of stenosis remained independently associated with the success rate. In 12 of the 15 patients (80%), the airway lumen beyond the stenotic lesion, which could not be reached by a standard bronchoscope, was successfully visualized and evaluated with a thin bronchoscope. No significant complications were associated with the procedures. Conclusion: The thin bronchoscope can be a useful tool for evaluating a severely stenosed airway during the stenting procedure.

Introduction

Central airway stenosis due to malignant or benign disease often causes a serious or even life-threatening condition. Interventional bronchoscopy, such as bronchoscopic ablation, ballooning or airway stenting, has become popular for rapid palliation of airway stenosis [1–4]. In the planning of interventional bronchoscopy, precise evaluation of the airway morphology, such as mucosal appearance, lesion length, degree of stenosis and airway patency distal to the lesion, is important. For evaluating the stenotic airway, several modalities, including computed tomography (CT) [5–13], ultrasonography [14–16] or bronchoscopy [5, 7–13, 16, 17], have been used. Above all, flexible bronchoscopy is the most precise and reliable method for evaluating endoluminal and mucosal lesions.

Key Words
Airway stent · Bronchoscopy · Central airway obstruction · Thin bronchoscope · Ultrathin bronchoscope

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[10, 13]. However, conventional bronchoscopy has the major limitation of being unable to reach the airway beyond the site of high-grade stenosis [7, 9–12, 17]. Recent advances in endoscopic technology have permitted the development of thin bronchoscopes with a number of significant characteristics, including thinner outer diameter, larger channel inner diameter and better visibility. So far, only thin bronchoscopes with a working channel of 1.2 mm or less have been available [16, 17], and eventually thin bronchoscopes with a 1.7-mm working channel were developed. Newly developed thin bronchoscopes with a 1.7-mm working channel have good bronchial selectivity and maneuverability even in a small airway, and their utility for the diagnosis of peripheral pulmonary lesions has been reported [18, 19]. The characteristics of the bronchoscopes also seem to be promising for assessing a stenosed central airway. The purpose of this study was to evaluate the usefulness of prototype thin flexible bronchoscopes for assessing a stenotic airway during the stenting procedure.

**Patients and Methods**

**Study Patients**

This prospective study was approved by the Institutional Review Board of Nagoya Medical Center (identifier: 2006-33). Between November 2006 and October 2009, 46 patients with central airway stenosis requiring stent implantation under general anesthesia were enrolled. Patients with mild stenosis in whom standard bronchoscope passage was confirmed prior to the intervention were excluded. Informed consent was obtained from all patients.

**Equipment**

For thin bronchoscopy, a prototype thin flexible bronchoscope (XBF-3B40Y1 or BF-Y0007; Olympus, Tokyo, Japan) was used (fig. 1). The XBF-3B40Y1 bronchoscopy has a 3.5-mm distal end diameter, a 1.7-mm working channel diameter, 180° up and 130° down angulation, a 90° field of view and a 2- to 50-mm depth of field. The BF-Y0007 hybrid bronchoscopy videomicroscope incorporates a charge-coupled device in the control section. It has a 3.4-mm distal end diameter and a 1.7-mm working channel diameter. For standard bronchoscopy, a commercially available 5.9- or 6.0-mm flexible bronchoscope (BF-1T30, BF-1T200 or BF-1T260; Olympus) was used (fig. 1).

**Procedures**

Preprocedural evaluation included chest X-ray and chest CT, which were performed in all patients. All procedures were performed using both rigid and flexible bronchoscopes under general anesthesia. After inserting a rigid tracheal tube (Efer-Du- mon, Efer, La Ciotat, France), flexible bronchoscopic evaluation using a standard bronchoscope through the rigid tracheal tube was performed. First, bronchoscopic observation of the stenosed lesion from a proximal view was performed, and the stenosis was categorized according to the following three grades: moderate (50% stenosis), severe (75% stenosis) or total (100% stenosis). The stenosis was also categorized from both the preprocedural CT and the bronchoscopic image according to the following stenotic types: intraluminal, extraluminal or mixed [1, 2]. Then passage through the narrowed lumen was attempted for viewing the airway distal to the stenotic lesion. When an intact bronchial spur or bronchial mucosa beyond the stenosed lesion was visualized, the passage of the bronchoscope was judged successful. Evaluation of the airways beyond the stenosed lesion with a thin bronchoscope was performed in patients in whom the standard bronchoscope failed to pass completely through the stenosed airway.

Following evaluation with the flexible bronchoscope, bronchoscopic treatment of the stenotic airway was performed. Before placing the stents, the airway lumen was reestablished by a bronchoscopic procedure combining argon plasma coagulation, electrocautery, balloon dilatation or rigid bronchoscopic debulking. After that, the length and diameter of the stenosis were assessed using a flexible and rigid bronchoscope, an endobronchial ultrasonic probe with a balloon and preprocedural static images as previously described [20]. In our institution, a silicone stent is preferred because of its removability, and so silicone stent placement using a rigid bronchoscope with or without fluoroscopic guidance was performed in most cases. In cases with tumor invasion beyond the segmental bronchi, stent placement was not performed.

**Statistical Analysis**

Statistical analyses were carried out using a statistical software program (PASW Statistics 18; SPSS Inc., Chicago, Ill., USA). Means and percentages were presented as appropriate. Results were analyzed using Fisher’s exact test. All variables which were significant at the 5% level in univariate analysis were tested using a multivariate logistic regression analysis. Results were considered statistically significant when the p value was ≤ 0.05.
Results

Characteristics of the patients and lesions are shown in table 1.

A standard bronchoscope could not pass through the stenotic airway in 15 of 46 patients (33%). On univariate analysis, the grade of stenosis (moderate or severe vs. total, p < 0.001), the presence or absence of atelectasis (p = 0.04) and the presence or absence of viscous secretions (p = 0.02) were related to the rate of successful passages by a standard bronchoscope while lesion location (solely the trachea vs. presence of bronchial lesions, p = 0.08) and stenotic type (intraluminal or mixed vs. extraluminal, p = 0.16) were not. On multivariate analysis, only the grade of stenosis remained independently associated with the success rate (table 2).

The characteristics and results of 15 patients in whom a standard bronchoscope could not pass through the stenosed lesion are detailed in table 3. In 12 of the 15 patients (80%), the airway lumen beyond the stenotic lesion, which could not be reached by a standard bronchoscope, was successfully visualized and evaluated with a thin bronchoscope. Representative cases are shown in figures 2 and 3.

Except for a small amount of bleeding, no complication associated with the use of a thin bronchoscope was observed.

Discussion

The result of this study indicates that the thin bronchoscope with a 1.7-mm working channel is a useful tool for evaluating narrowed airways during therapeutic bronchoscopic procedures. The thin bronchoscope was able to pass completely through the stenosed airway in 80% of cases in which a standard-sized bronchoscope failed to pass.

Assessment of luminal characteristics with a thin bronchoscope, especially the airway beyond the narrowing site, is very helpful for planning interventional procedures. The assessment of lesion location influences the decision as to bronchoscopic management. Since the indication for
airway stenting is proximal to the segmental bronchi, stenting is contraindicated if tumor invasion at the level of segmental bronchi is proven on bronchoscopy [20, 21]. Assessment of lesion length also provides important information, including selection of the bronchoscopic modality for airway dilatation and choice of stent length. Assessment of the luminal route allows safe and efficient reestablishment of the airway lumen. Although bronchoscopic reestablishment should be performed along the original airway lumen, in certain cases with total obstruction, the course of the original airway lumen is not clear. The pathway through which the thin bronchoscope passed is very useful for orientation in therapeutic bronchoscopy including dilations and ablations. Furthermore, the pathway established by the passage of the thin bronchoscope or thin-bronchoscopic suction of deposited mucus may contribute to efficient ventilation during general anesthesia.

So far, few investigators have reported on the utility of an ultrathin bronchoscope for evaluating a stenosed central airway [16, 17]. In the study of Schuurmans et al. [17], a total of 24 patients with central airway obstruction underwent ultrathin bronchoscopy under local anesthesia using a bronchoscope with an outer diameter of 2.8 mm and a working channel of 1.2 mm. In 87% of these patients, the ultrathin bronchoscope was able to pass the obstructing lesion and allowed assessment of the obstruction and the distal airways. Although the authors concluded that an ultrathin bronchoscope was a useful and safe tool for the assessment of patients with central airway obstruction, they mentioned its limited ability including the poor suction capability of the small-caliber working channel or a limp shaft. To overcome these limitations, the use of a thin bronchoscope, which has a larger working channel and a larger shaft than an ultrathin bronchoscope, is likely to be preferable, especially under general anesthesia. In our study, the distal airway beyond the stenosed lesion, which a standard bronchoscope could not reach, was filled with viscous secretions in 73% of the cases. Such viscous secretions tend to plug the working channel and cannot be suctioned on a single try in most cases. However, the setting with a rigid bronchoscope under general anesthesia readily allows the frequent insertion and extraction of a thin bronchoscope. Additionally, the rigidity of the bronchoscope may be an important factor for passing the

<table>
<thead>
<tr>
<th>Variables</th>
<th>Odds ratio</th>
<th>p value</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade of stenosis, total versus others</td>
<td>14.17</td>
<td>0.02</td>
<td>1.53–131.55</td>
</tr>
<tr>
<td>Atelectasis, presence versus absence</td>
<td>0.52</td>
<td>0.46</td>
<td>0.09–2.92</td>
</tr>
<tr>
<td>Viscous secretions, presence versus absence</td>
<td>0.68</td>
<td>0.71</td>
<td>0.09–5.34</td>
</tr>
</tbody>
</table>

Fig. 3. a Chest CT showing left main bronchial stenosis due to lung cancer. b Bronchoscopic view with a standard-sized bronchoscope. Left main stem bronchus was obstructed. c Bronchoscopic view with a thin bronchoscope. Thin bronchoscope could pass the obstructing lesion, and the left upper division bronchus was observed.

Table 2. Multivariate logistic regression analysis of factors associated with the rate of successful passage of a standard bronchoscope

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stenosed lesion. To pass a stenosed site, a force must be transmitted to the tip of the bronchoscope. However, the force may not be directly transmitted to the tip of an ultrathin bronchoscope, given the limpness of its shaft.

Recent technological advances in radiology, especially in CT technology, have revolutionized noninvasive assessment of central airways. Two-dimensional multiplanar reconstruction methods and three-dimensional reconstruction methods, including internal rendering, i.e., so-called ‘virtual bronchoscopy’, and external rendering, provide excellent anatomical images of airways, thereby overcoming the limitations of conventional axial CT images [22]. Virtual bronchoscopy produces images that are very similar to those provided by conventional bronchoscopy, and this seems promising because of its noninvasiveness and simplicity. Virtual bronchoscopy is reportedly advantageous in comparison with conventional bronchoscopy because it can produce images of inner airways.

Table 3. Details of 15 patients in whom a standard bronchoscope failed to pass the stenosed lesion

<table>
<thead>
<tr>
<th>No.</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Disease</th>
<th>Location of stenosis</th>
<th>Stenosis type</th>
<th>Stenosis grade</th>
<th>Atelectasis</th>
<th>Viscous secretions</th>
<th>Thin bronchoscope</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52</td>
<td>F</td>
<td>Breast cancer</td>
<td>Trachea, LMSB</td>
<td>Mixed</td>
<td>Severe</td>
<td>–</td>
<td>–</td>
<td>Passed</td>
<td>APC, electrocautery, ballooning, silicone stenting</td>
</tr>
<tr>
<td>2</td>
<td>59</td>
<td>M</td>
<td>Lung cancer</td>
<td>LMSB</td>
<td>Intraluminal</td>
<td>Severe</td>
<td>LUL</td>
<td>–</td>
<td>Not passed due to invasion of peripheral airway</td>
<td>APC, electrocautery</td>
</tr>
<tr>
<td>3</td>
<td>72</td>
<td>F</td>
<td>Esophageal cancer</td>
<td>LMSB</td>
<td>Mixed</td>
<td>Occlusion</td>
<td>LUL</td>
<td>+</td>
<td>Passed</td>
<td>APC, electrocautery, ballooning, silicone stenting</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>F</td>
<td>Tuberculosis</td>
<td>LMSB</td>
<td>Intraluminal</td>
<td>Occlusion</td>
<td>Left lung</td>
<td>+</td>
<td>Not passed due to high-grade stenosis</td>
<td>Ballooning, silicone stenting</td>
</tr>
<tr>
<td>5</td>
<td>67</td>
<td>M</td>
<td>Renal cancer</td>
<td>RMSB</td>
<td>Intraluminal</td>
<td>Occlusion</td>
<td>–</td>
<td>+</td>
<td>Not passed due to a small amount of bleeding</td>
<td>APC, electrocautery, silicone stenting</td>
</tr>
<tr>
<td>6</td>
<td>68</td>
<td>M</td>
<td>Granulomatosis with polyangiitis (Wegener’s)</td>
<td>LMSB</td>
<td>Intraluminal</td>
<td>Occlusion</td>
<td>LUL</td>
<td>+</td>
<td>Passed</td>
<td>Ballooning, silicone stenting</td>
</tr>
<tr>
<td>7</td>
<td>63</td>
<td>M</td>
<td>Esophageal cancer</td>
<td>LMSB</td>
<td>Mixed</td>
<td>Occlusion</td>
<td>–</td>
<td>+</td>
<td>Passed</td>
<td>APC, ballooning, silicone stenting</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>M</td>
<td>Lung cancer</td>
<td>BI</td>
<td>Mixed</td>
<td>Occlusion</td>
<td>Right lung</td>
<td>–</td>
<td>Passed</td>
<td>APC, electrocautery, ballooning, silicone stenting</td>
</tr>
<tr>
<td>9</td>
<td>61</td>
<td>M</td>
<td>Lung cancer</td>
<td>RMSB, BI</td>
<td>Mixed</td>
<td>Occlusion</td>
<td>–</td>
<td>+</td>
<td>Passed</td>
<td>Silicone stenting</td>
</tr>
<tr>
<td>10</td>
<td>51</td>
<td>M</td>
<td>Esophageal cancer</td>
<td>Trachea, RMSB</td>
<td>Mixed</td>
<td>Occlusion</td>
<td>–</td>
<td>+</td>
<td>Passed</td>
<td>APC, electrocautery, silicone stenting</td>
</tr>
<tr>
<td>11</td>
<td>70</td>
<td>F</td>
<td>Postoperative stenosis</td>
<td>LMSB</td>
<td>Intraluminal</td>
<td>Occlusion</td>
<td>–</td>
<td>–</td>
<td>Passed</td>
<td>APC, electrocautery</td>
</tr>
<tr>
<td>12</td>
<td>62</td>
<td>F</td>
<td>Lung cancer</td>
<td>LMSB</td>
<td>Mixed</td>
<td>Occlusion</td>
<td>–</td>
<td>+</td>
<td>Passed</td>
<td>Ballooning, silicone stenting</td>
</tr>
<tr>
<td>13</td>
<td>81</td>
<td>M</td>
<td>Rectal cancer</td>
<td>LMSB</td>
<td>Intraluminal</td>
<td>Occlusion</td>
<td>LLL</td>
<td>+</td>
<td>Passed</td>
<td>APC, electrocautery, silicone stenting</td>
</tr>
<tr>
<td>14</td>
<td>68</td>
<td>M</td>
<td>Esophageal cancer</td>
<td>LMSB</td>
<td>Mixed</td>
<td>Occlusion</td>
<td>LLL</td>
<td>+</td>
<td>Passed</td>
<td>APC, electrocautery, ballooning, silicone stenting</td>
</tr>
<tr>
<td>15</td>
<td>75</td>
<td>F</td>
<td>Lung cancer</td>
<td>RULB</td>
<td>Intraluminal</td>
<td>Occlusion</td>
<td>–</td>
<td>+</td>
<td>Passed</td>
<td>APC, electrocautery</td>
</tr>
</tbody>
</table>

LMSB = Left main stem bronchus; RMSB = right main stem bronchus; BI = bronchus intermedius; RULB = right upper lobe bronchus; LUL = left upper lobe; LLL = left lower lobe; APC = argon plasma coagulation.
way surfaces beyond a site of stenosis which conventional bronchoscopes cannot pass [9–12]. However, low sensitivity for mucosal abnormalities is a serious limitation for assessing the extent of airway wall involvement [9, 10, 12]. Furthermore, it sometimes mistakenly displays viscous secretions as stenoses or occlusions [9, 11]. Undoubtedly, these CT modalities are very useful for preprocedural evaluation of central airway stenosis, but the initial thin-bronchoscopic evaluation just before the interventional procedures in the same session provides more accurate information for determining the feasibility of therapeutic bronchoscopic procedures.

The limitation of this study was that the end point was the rate of successful passages of the thin bronchoscope but not direct evaluation of the utility of the thin bronchoscope for treatment planning. To elucidate the usefulness of thin bronchoscopy in more detail, randomized trials of thin bronchoscopy versus standard bronchoscopy in the bronchoscopic treatment of stenosed airways may be needed.

In conclusion, a thin bronchoscope with a 1.7-mm working channel can be a useful tool for evaluating a severely stenosed airway during the stenting procedure. We hope that thinner bronchoscopes with a larger working channel and better visibility will be developed for more promising evaluation of stenosed central as well as peripheral airways.

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References