Interventional Bronchoscopy in the Management of Airway Stenosis Due to Tracheobronchial Tuberculosis*

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Study objectives: To assess the efficacy and complications of interventional bronchoscopic techniques in treating airway stenosis due to tracheobronchial tuberculosis.

Design: Case series.

Setting: Respiratory care centers at two tertiary care referral teaching hospitals in Japan, Hiroshima City Hospital and Okayama Red Cross Hospital.

Patients and interventions: A total of 30 patients were admitted to the hospital with a diagnosis of tracheobronchial tuberculosis between January 1991 and January 2002. Of those 11 patients received interventional bronchoscopy, including stent placement, laser photoresection, argon plasma coagulation (APC), balloon dilatation, cryotherapy, and endobronchial ultrasonography (EBUS). One patient with complete bronchial obstruction underwent a left pneumonectomy.

Results: Six patients underwent stent placement after balloon dilatation, while the remaining five patients underwent only balloon dilatation. In six patients, Dumon stents were successfully placed to reestablish the patency of the central airways. Two patients first had Ultraflex stents implanted but had problems with granulation tissue formation and stent deterioration caused by metal fatigue due to chronic coughing. Dumon stents then were placed within the Ultraflex stents after the patient had received treatment with APC and mechanical reaming using the bevel of a rigid bronchoscope. In four patients, EBUS images demonstrated the destruction of bronchial cartilage or the thickening of the bronchial wall. The main complications of Dumon stents are migration and granulation tissue formation, necessitating stent removal, or replacement, and the application of cryotherapy to the granuloma at the edge of the stent.

Conclusion: Interventional bronchoscopy should be considered feasible for management of tuberculous tracheobronchial stenosis. Dumon stents seem to be appropriate, since removal or replacement is always possible. Ultraflex stents should not be used in these circumstances because removal is difficult and their long-term safety is uncertain. EBUS could provide useful information in evaluating the condition of the airway wall in cases of tracheobronchial tuberculosis with potential for bronchoscopic intervention.

Key words: balloon dilatation; endobronchial ultrasonography; stent placement; tracheobronchial stenosis

Abbreviations: APC = argon plasma coagulation; EBUS = endobronchial ultrasonography

Tuberculous tracheobronchial stenosis is a serious clinical problem because it can cause obstructive pneumonia and dyspnea on exertion. Surgical resection and bronchoplastic reconstruction has long been the standard treatment. More recently, a variety of interventional bronchoscopic techniques has been developed, including stent placement, laser photoresection, argon plasma coagulation (APC), balloon dilatation, cryotherapy and endobronchial ultrasonography (EBUS). The development and refinement of various airway stents and increased experience have broadened the indications for these procedures. We reported previously that stenting has become a valuable new therapeutic strategy for patients with malignant or benign tracheobronchial stenosis. However, the indications for...
stenting in patients with tuberculous tracheobronchial stenosis are difficult to understand, and prognosis is unclear. We carefully evaluated what might be the best interventional strategy in this complex situation.

EBUS has been used in recent years to evaluate the individual layers of the bronchial wall. In our previous study, the images produced by EBUS correlated with histologic results. The third layer (hyperechoic) is the marginal echo on the inner side of the bronchial cartilage, and the fourth layer (hypoechoic) is the bronchial cartilage. Thus, we considered that EBUS might provide useful information for a planned bronchoscopic intervention.

This report highlights patients with tracheobronchial tuberculosis in whom diagnosis and treatment were made by various methods of interventional bronchoscopy, including EBUS and stent placement for stenoses.

**Patients and Methods**

From January 1991 to January 2002, 30 patients with tracheobronchial tuberculosis were admitted to our institutions. Among these patients, treatment with antituberculous medication resulted in 18 patients recovering and remaining asymptomatic. However, 12 patients developed dyspnea, severe cough, and repeated obstructive pneumonia due to tracheobronchial stenosis. These 12 patients were considered to be suitable candidates for intervention (bronchoscopy, 11 patients; pneumonectomy, 1 patient). The clinical characteristics are presented in Table 1. All patients were examined by flexible bronchoscopy (BF200; Olympus, Tokyo, Japan). The sites of bronchial lesions in each patient are also shown in Table 1. Before bronchoscopic intervention, written informed consent was obtained from all patients.

After balloon dilatation (Accent Balloon Angioplasty Catheters; Cook Inc, Bloomington, IN) as well as gentle dilatation with the bevel of a rigid bronchoscope (Efer; La Ciolat, France) under general anesthesia and fluoroscopic visualization, the Dumon stent (Novatech; Aubagne, France) and the Ultraflex stent (Boston Scientific; Natick, MA) were placed according to the technique recommended by their originators.

Endobronchial APC (APC; Erbe USA; Marietta, GA) was performed via a flexible bronchoscope (energy applied, 30 to 40 W; argon flow, 1.6 L/min). A monopolar APC probe, 220 cm in length and 2.3 mm in diameter, was inserted through the working channel of the bronchoscope. The target tissue was visualized endoscopically and then coagulated. The coagulated tissue then was removed mechanically with grasping forceps.

Cryotherapy was performed with a rigid cryoprobe (142 Cryo Unit; Spenbly Medical; Andover, UK) through a rigid bronchoscope. Liquid carbon dioxide was used as the cooling agent, which could reach a low temperature (~70°C). The metallic tip of the cryoprobe was placed on the tumor or the granulation tissue, and a freeze-thaw procedure was initiated, with each freeze-thaw cycle lasting about 30 s, and was carried out in three cycles at several points until the entire visible lesion had been frozen. Tissue necrosis usually occurs 8 to 15 days following the procedure.

For the EBUS procedure (EU-M 20; Olympus), a 2.5-mm diameter, 20-MHz frequency radial mechanical transducer-type ultrasonic probe (UM-3R; Olympus, Tokyo, Japan) and a flexible balloon sheath equipped with a balloon at the tip (MH-246R; Olympus) were used. We introduced them through the 2.8-mm diameter channel of a flexible bronchoscope (BF-1T20; Olympus).

**Results**

**Clinical Summary**

Twelve patients who had a diagnosis of tracheobronchial tuberculosis were treated in our hospital.

<table>
<thead>
<tr>
<th>Patient/Sex/Age, yr</th>
<th>Symptoms</th>
<th>Sites of Lesions</th>
<th>Intervention</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/F/59</td>
<td>Dyspnea</td>
<td>Trachea, carina, LMB</td>
<td>Balloon, Dumon Y, EBUS</td>
<td>Improved</td>
</tr>
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<td>2/F/29</td>
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<td>LMB</td>
<td>Balloon, Dumon, EBUS</td>
<td>Improved</td>
</tr>
<tr>
<td>3/M/59</td>
<td>Dyspnea</td>
<td>LMB</td>
<td>Balloon, Dumon, EBUS</td>
<td>Improved</td>
</tr>
<tr>
<td>4/M/65</td>
<td>Dyspnea</td>
<td>Trachea</td>
<td>Balloon, Dumon Y, EBUS</td>
<td>Improved</td>
</tr>
<tr>
<td>5/F/48</td>
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<td>Trachea, carina, RMB</td>
<td>Balloon, APC, cryotherapy, Ultraflex, Dumon Y</td>
<td>Improved</td>
</tr>
<tr>
<td>6/F/56</td>
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<td>Trachea</td>
<td>Balloon, APC, cryotherapy, Ultraflex, Dumon</td>
<td>Improved</td>
</tr>
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<td>7/F/77</td>
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<td>RMB</td>
<td>Balloon</td>
<td>Improved</td>
</tr>
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<td>LMB</td>
<td>Balloon</td>
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<td>LMB</td>
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<td>Unchanged</td>
</tr>
<tr>
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<td>LMB</td>
<td>Balloon</td>
<td>Unchanged</td>
</tr>
<tr>
<td>11/F/31</td>
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<td>LMB</td>
<td>Balloon</td>
<td>Unchanged</td>
</tr>
<tr>
<td>12/F/19</td>
<td>Dyspnea</td>
<td>LMB</td>
<td>Left pneumonectomy</td>
<td>Improved</td>
</tr>
</tbody>
</table>

*RMB = right main bronchus; LMB = left main bronchus; F = female; M = male.*
The clinical characteristics are presented in Table 1. Dyspnea was documented in 11 patients, and cough was documented in 1 patient. The sites of the lesions were as follows: left main bronchus, 8 patients; trachea, 4 patients; right main bronchus, 2 patients; and carina, 2 patients. Tracheobronchial stents were inserted after balloon dilatation in 6 of the 12 patients. Three patients received Dumon straight stents, and the remaining 3 patients received Dumon Y-stent. Patients 5 and 6 had previously undergone implantation of Ultraflex stents, but granulation tissue had grown through the mesh of the stent.

In patients 1 to 4, EBUS was performed to evaluate the condition of the bronchial wall before stenting. Patients 5 and 6 required cryotherapy directed to granulation tissue at the edge of a Dumon stent. Patients 5 and 6 required APC to treat granulation tissue through the mesh. Patient 6 had damage to the mesh of the stent caused by metal fatigue from chronic coughing. Dumon stents were inserted through the previously implanted Ultraflex stents. Patients 7 through 11 were treated solely with balloon dilatation under local anesthesia. Patients 7 and 8, who had strictures of the right main bronchus and left main bronchus, showed decreased symptoms of dyspnea. The remaining three patients had shown little response and experienced early relapse. Patient 12 underwent a left pneumonectomy.

**Case Reports**

Patient 1 was diagnosed with tracheobronchial tuberculosis. The patient had been treated with antituberculous medications for 3 months, and then was referred to our hospital because of persistent dyspnea on exertion. Bronchoscopy revealed a pinhole stenosis of the left main bronchus. We initially performed balloon dilatation of the left main bronchus, but the stenosis recurred rapidly. We therefore placed a Dumon stent in the left main bronchus. During the next 2 months, the patient complained of progressive dyspnea. We performed rigid bronchoscopy, which revealed migration of the stent, retained secretions within the stent, and dynamic collapse of the trachea. After the removal of the stent the carina was patent during positive-pressure ventilat-

![Figure 1](image-url)
tion but collapsed if positive-pressure ventilation was discontinued (Fig 1, top left, A). Tracheobronchoplastic surgery was impossible to perform as the affected segment, extending from the trachea into the main bronchus, was too long. Therefore, we placed a Dumon Y-stent to prevent airway compression during exhalation (Fig 1, top middle, B). In this case, with variable tracheobronchial stenosis, the flow-volume curve was represented by a dotted line with the descending expiratory limb showing marked reduction of airflow. Following stenting, the flow-volume curve, represented by a bold line in Figure 1, top right, C, returned to near normal. Before stenting, on visualizing the layers of the tracheal wall by EBUS, the normal horseshoe-shaped cartilage could not be seen for a 4-cm length from the carina to the left main bronchus (Fig 1, bottom, D). Follow-up bronchoscopic examination confirmed that the airway was patent. The patient has remained asymptomatic for 4 years after stenting, during which period the stent has been replaced twice.

Patient 2 presented with fever. A chest radiograph showed infiltrates in the left lung. Bronchial tuberculosis was diagnosed by bronchoscopy. After the completion of a course of antituberculous medication, she experienced three episodes of obstructive pneumonia. Bronchoscopy revealed a central pinhole stenosis of the left main bronchus (Fig 2, top left, A). The patient was referred to our hospital but refused to undergo surgery, thus we placed a Dumon stent (diameter, 10 mm; length, 40 mm) after sequential dilation of the airway with progressively larger balloons (Fig 2, top middle, B). One year later, we removed the stent, and the patient remained asymptomatic. Follow-up bronchoscopic examination confirmed patency of the left main bronchus (Fig 2, top right, C). The bronchial wall was thickened, and the bronchial cartilage appeared intact on EBUS imaging (Fig 2, bottom left, D). In this patient with bronchial stenosis, the decreased expiratory flow-volume curve improved following the placement of the stent. Stenting resulted in a marked rightward, nearly parallel shift of the descending expiratory limb of the flow-volume curve (Fig 2, bottom right, E). We successfully performed bronchoscopic interventions to prevent obstructive pneumonia. She has been well and asymptomatic for 2 years.

Patient 3, who had been previously admitted to our hospital with tracheobronchial tuberculosis and had been receiving medication for 1 year, was readmitted with progressive dyspnea. Bronchoscopic examination revealed a slit-like stenosis of the left main bronchus. We inserted a Dumon stent following balloon dilatation after EBUS imaging showed a thickening of the bronchial wall.
bronchial wall. Although the patient’s symptoms immediately improved, they recurred 2 months later. Bronchoscopic examination revealed an occlusion at the distal side of the stent due to granulation tissue formation. The stent was extracted, and granulation tissue regressed spontaneously. The left main bronchus was clearly patent when examined 1 month after the procedure, suggesting that the stent had accomplished effective dilatation.

The patient has remained asymptomatic for 6 months.

Patient 4 was admitted to our hospital with progressive dyspnea after 7 months of follow-up for tracheal tuberculosis. Bronchoscopic examination revealed slit-like tracheal stenosis (Fig 3, top left, A). To prevent suffocation, we inserted a Dumon Y-stent after balloon dilatation (Fig 3, top middle, B). After stenting, the FEV1 increased from 700 to 2,080 mL. In this patient with severe stenosis due to tracheal tuberculosis, the flow-volume curve showed marked reduction of the expiratory flow, with a plateau which is typically seen with fixed narrowing of the trachea. After placement of the Dumon Y-stent, the plateau was no longer apparent, and the flow increased (Fig 3, top right, C). The tracheal wall was thickened, and the horseshoe-shaped tracheal cartilage could not be seen for two rings according to the EBUS imagery (Fig 3, bottom left, D). We replaced the tracheal stent, and the patient has been well for 6 months since undergoing stenting.

In patient 5, tracheobronchial tuberculosis had been diagnosed at another institution 10 years previously. She had had a tracheal Dumon stent for 8 years. It was then removed because of granulation tissue formation at the stent edges. The patient had subsequently undergone implantation of Ultraflex nitinol stents in the trachea and right main bronchus at the same institution. The patient had required laser photoresection > 40 times in 2 years to remove granulation tissue. The patient was referred to our hospital in acute respiratory distress for emergency treatment. The airway had become extremely narrowed by granulation tissue ingrowth through the mesh of the stent (Fig 4, top left, A, and top right, B). We first resected some granulation tissue by APC, and then reamed it mechanically using the bevel of a rigid bronchoscope. At this point, we successfully removed the Ultraflex stent from the right main bronchus using rigid forceps. This stent had unraveled and was extracted completely. The tracheal stent remained in situ. A long Dumon Y-stent was placed within the tracheal Ultraflex nitinol stent after balloon dilatation (Fig 4, bottom left, C, and bottom right, D). The airway was clearly patent for 1 year after the procedure, when the patient complained of progressive dyspnea. Bronchoscopic examination revealed granulation tissue at the edge of the Dumon stent, and cryotherapy was performed to freeze it. The patient returned home in good health and has had no need of further treatment for 9 months.

Patient 6 was admitted to our hospital with tracheal tuberculosis.
Figure 4. Patient 5. Top left, A: rigid bronchoscopy shows stenosis of the trachea caused by granulation tissue protruding through the mesh of an Ultraflex stent. Top right, B: coronal plane chest CT scan imagery obtained before the placement of a Dumon Y-stent shows an irregular intraluminal narrowing of the trachea due to granulation tissue growing through the mesh of an Ultraflex stent. Bottom left, C: rigid bronchoscopy shows the re-establishment of tracheal patency after the placement of a Dumon Y-stent. Bottom right, D: coronal plane chest CT scan image shows wide patency of the trachea after the placement of a Dumon Y-stent within the Ultraflex stent. Cryotherapy was performed to freeze granulation tissue at the edge of the Dumon stent.

Interventional bronchoscopy is an alternative treatment strategy to surgical resection in the management of stenosis resulting from tracheobronchial tuberculosis.1,2 Basically, stenting should be performed after balloon dilatation when the patients prove to be smear-negative for tuberculosis. Because stent-related complications are observed frequently...
in patients with benign stenosis caused by tracheobronchial tuberculosis, a removable stent should be selected. Thus, the Dumon stent is particularly suitable for patients with tuberculous tracheobronchial stenosis, and in our series it caused fewer complications than an expandable metallic stent. We succeeded in identifying the nature of the stenosis caused by tracheobronchial tuberculosis using serial flow-volume curves (ie, whether it was due to fixed narrowing or to dynamic collapse). EBUS imaging was useful in making a diagnosis of cartilaginous tracheobronchomalacia and in aiding the decision as to whether or not a stent was needed. In this study, we used EBUS imaging to evaluate the condition of tracheobronchial cartilage, which is important in assessing the tracheobronchial wall before the placement of a stent. To the best of our knowledge, this is the largest series of tuberculous tracheobronchial stenoses treated with interventional bronchoscopy and the first report using EBUS imaging to demonstrate the destruction of tracheobronchial cartilage due to tracheobronchial tuberculosis.

Balloon dilatation for tracheobronchial stenosis was first described by Cohen et al,11 and Nakamura et al16 used this technique to treat tuberculous tracheobronchial stenosis. Balloon dilatation for tuberculous tracheobronchial stenosis is usually straightforward and minimally invasive, and can be performed under local anesthesia. It is particularly appropriate for annular cicatricial stenosis, since the balloon dilates the stenotic bronchus by expanding radially. This approach is the initial treatment of choice for tracheobronchial steno-

Figure 5. Patient 6. Top left, A: a bronchoscopic examination shows the pinhole stenosis of the trachea (black arrow) and the fistula to the esophagus (white arrow). Top right, B: bronchoscopic examination shows the trachea to be patent after the implantation of a covered Ultraflex stent. Bottom left, C: 17 months after the implantation of a covered Ultraflex stent, bronchoscopic examination revealed the deterioration of the stent (black arrow) from metal fatigue caused by repeated coughing, as well as granulation tissue formation at the edge of the stent (white arrow). Bottom right, D: bronchoscopic examination shows the re-establishment of tracheal patency after the placement of a Dumon stent within the covered Ultraflex stent.
The Dumon stent is widely used, and is considered to be a “gold standard” because it is economical, readjustment is simple, and removal and replacement are always possible. Most stents are straight, which is a design that is not well-suited for lesions near the carina because they may migrate. With the Dumon Y-stent, which is designed for lesions of the carina, there are fewer problems with migration because of its shape. Nomori et al reported stenosis from granulation tissue at the edges of a Dumon stent placed to treat a tuberculous tracheobronchial stenosis. We performed cryotherapy to freeze edge granulation tissue successfully.

More recently, a self-expandable stent made of the metallic alloy nitinol, the Ultraflex stent, has become widely used for the treatment of tracheobronchial stenosis due to malignant tumors. Ducic and Khalafi reported that the Ultraflex stent also relieved tracheal stenosis due to benign causes without complications. Jantz and Silvestri reported no granulation tissue formation with either the covered or uncovered Ultraflex stent in 16 patients, regardless of diagnosis. However, in the cases we examined, the airway had been narrowed by granulation tissue ingrowth through the mesh of the nitinol stent, requiring APC and debulking. Granulation tissue formation was sometimes seen at the edge of the covered Ultraflex stent. Ultraflex stents have caused fewer complications in tracheobronchial stenosis caused by tracheobronchial tuberculosis than other expandable metallic stent such as the Gianturco stent. Even if a stent is epithelialized, removal is possible by means of rigid bronchoscopy. However, removal was difficult. The dynamic properties of this stent may lead to its fracture due to metal fatigue with severe repeated coughing. Severe dyspnea caused by granulation tissue formation was immediately relieved by the placement of Dumon stents within the uncovered nitinol stents.

In one patient with tracheobronchial malacia necessitating long-term placement of a Dumon Y-stent, the Y-stent was replaced twice within 4 years. The decision as to whether a patient with tracheobronchial tuberculosis is a better candidate for surgery or stent placement is very complex. Kato et al suggested that surgery should be the therapy of choice in patients who can tolerate it. A stent should be placed only if the patient is definitely inoperable. In our cases of stenosis due to tracheobronchial tuberculosis, only one patient with complete bronchial obstruction underwent a left pneumonectomy. Dilatation of the cicatricial stenosis was rarely long-lasting, and stent placement was performed temporarily. Two patients were spared surgery by means of temporary stenting. Schmidt et al reported that the stents can be removed when inflammation has diminished and severe malacia is absent in cases of benign tracheobronchial stenosis.

Diffuse tracheobronchial stenosis due to tuberculosis poses many problems. If a stent is decided on as the means of treatment, then the demerits of stent migration, granulation, retained secretions, and stent fracture must be considered. The stent may have to be removed and be replaced by a longer stent (eg, by a Y-stent). Therefore, the long Dumon Y-stent appears to be particularly good for treating diffuse tracheobronchial stenosis due to tuberculosis.

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