Combined Endoscopic and Open Approach to the Removal of Expandable Metallic Tracheal Stents

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Objectives: To review complications of indwelling tracheal stents and to describe a technique of stent removal using a combined open and endoscopic approach.

Design: Descriptive case series.

Setting: Medical University of South Carolina.

Patients: Six patients were identified who had undergone combined open and endoscopic removal of indwelling tracheal stents. Coated (4 patients) and uncoated (2 patients) expandable metal stents had been present for an average time of 24 months (range, 5-60 months) before removal.

Main Outcome Measures: Medical comorbidities, characteristics of the underlying airway lesion (origin, type, and length), stent characteristics (type and duration), and the presentation and management of stent-related complications.

Results: All patients presented with worsening dyspnea and/or stridor, with 3 requiring intubation. Stent removal was performed in the operating room and consisted of initial exposure of the trachea for emergency airway access, removal of the indwelling stent under bronchoscopic and transtracheal guidance, and tracheotomy. Two patients experienced desaturations of more than 25% during the procedure, and 2 patients had stents that could be only partially removed. Five patients subsequently received Montgomery T-tubes without complications after a mean follow-up of 23 months (range, 6-40 months).

Conclusions: Indwelling tracheal stents are becoming increasingly common in the management of benign airway stenosis. The stents frequently occlude with granulation tissue and may require removal. A combined open and endoscopic removal maximizes airway protection and minimizes potential complications.

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Benign and malignant tracheal stenosis are relatively common conditions that are associated with a high degree of morbidity and the risk of death from airway obstruction. Surgical resection and reconstruction are the preferred treatments for these lesions; however, surgery may not be an option if there is advanced or metastatic cancer, multiple medical comorbidities, or extensive involvement of the trachea and major bronchi. In such cases, a tracheal stent may be a viable treatment alternative.

The tracheal stents currently in use fall into 2 broad categories: silicone and metallic. Silicone stents are older and more widely used in the treatment of benign conditions. The first silicone stent was the Montgomery T-tube, which was introduced in 1964. Although various alterations of the Dumon T-tube have been devised, the Dumon stent is by far the most widely used today. The Dumon stent is essentially a Montgomery T-tube with the horizontal limb removed and silicone studs added along the length of the tube to prevent migration. Nevertheless, the migration rate in benign disease can be as high as 18%. Additionally, silicone stents can be inserted only using rigid bronchoscopy, thereby requiring that the patient receive general anesthesia for stent placement. Self-expanding metallic stents were initially adapted for the airways from those used in the esophagus, bile ducts, and vascular tree. These stents are generally made from a nitinol base, which has shape memory so that they can be constrained on a delivery system but resume their original diameter on release. They can be placed with the patient using local anesthesia and conscious sedation in an outpatient setting. However, once metallic stents are in for more than 4 to 6 weeks, they can become epithelialized, thus making them difficult if not impossible to remove. Originally used for malignant airway obstruction, metallic stents have become increasingly used in the treatment of benign tracheal stenosis.

Although application of tracheal stents to unresectable malignant lesions provides significant palliation and is generally well accepted in the literature, stent placement for benign lesions is a source of significant controversy. This controversy especially holds true with regard to placement of metallic stents. Little is known about the op-
timal types of stent to use, the optimal methods of placement, or the length of treatment in a given clinical scenario. Complications such as stent fracture, stent migration, formation of granulation tissue, or tumor ingrowth can necessitate stent removal.8-12 These complications are not uncommon, with 25% to 50% of patients requiring removal by 16 months.13,14 Maintaining adequate airway protection during stent removal remains a challenging problem.3,15 This study reviews complications of indwelling tracheal stents and describes a technique of stent removal using a combined open and endoscopic approach developed to maximize airway protection at the time of stent removal.

METHODS

The present study is a descriptive case series of the presentation and treatment of 6 patients with complications related to indwelling metallic tracheal stents. All patients were treated at the Medical University of South Carolina, a tertiary care referral center in Charleston. The study was approved by the Medical University of South Carolina institutional review board.

Patient information was obtained by retrospective review of the Medical University of South Carolina electronic medical record and outpatient medical records. Data recorded included patient demographics (age, race, and sex), medical comorbidities, characteristics of the underlying airway lesion (origin, type, and length), stent characteristics (type and duration), and the presentation and management of stent-related complications.

RESULTS

Between 2002 and 2005, 1 adolescent and 5 adult patients presented to the Medical University of South Carolina with complications related to indwelling metallic tracheal stents (3 female and 3 male patients; mean age, 52 years; age range, 16-79 years). Baseline patient characteristics are provided in Table 1. Tracheomalacia was the underlying airway lesion in 4 patients, whereas 2 patients had both tracheomalacia and subglottic stenosis. The mean length of airway collapse was 8.7 cm (range, 7-11 cm). The origin of the airway lesion was prolonged intubation in 4 patients and prolonged tracheal compression from a substernal goiter in 2 patients. The 2 patients with goiter-related tracheomalacia underwent successful total thyroidectomy before presentation without relief of the tracheomalacia. All but 1 patient was obese, defined as a body mass index (calculated as weight in kilograms divided by height in meters squared) greater than 30. Five of the 6 patients had at least 1 significant medical comorbidity. Comorbidities included hypertension (4), chronic obstructive pulmonary disease (4), coronary artery disease (3), atrial fibrillation (2), type 2 diabetes mellitus (2), chronic renal failure (1), and vasculitis (1). Four were former smokers and 3 had been previously diagnosed as having obstructive sleep apnea. All 6 had symptoms (phlegm, throat clearing, globus sensation, hoarseness, and sore throat) and laryngoscopic findings (glottic and interarytenoid edema and erythema) consistent with laryngopharyngeal reflux disease, requiring management with proton pump inhibitors and reflux precautions.

All 6 patients had previously been treated with either coated (4 patients) or uncoated (2 patients) expandable metallic stents (Table 2). The average time since stent placement was 24 months (range, 5-60 months). All patients presented with progressive dyspnea and air hunger on exertion. One patient had recurrent episodes of

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**Table 1. Baseline Characteristics of Patients Who Required Indwelling Stent Removal**

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Race</th>
<th>Cause of Airway Obstruction</th>
<th>Airway Lesion</th>
<th>Length of Lesion, cm</th>
<th>Comorbidities, No.</th>
<th>Obesity (BMI &gt;30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/79</td>
<td>W</td>
<td>Goiter</td>
<td>TM</td>
<td>8</td>
<td>4</td>
<td>Yes</td>
</tr>
<tr>
<td>2/F/16</td>
<td>B</td>
<td>Prolonged intubation</td>
<td>SS, TM</td>
<td>11</td>
<td>0</td>
<td>No</td>
</tr>
<tr>
<td>3/M/64</td>
<td>W</td>
<td>Prolonged intubation</td>
<td>TM</td>
<td>9</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>4/F/64</td>
<td>W</td>
<td>Prolonged intubation</td>
<td>TM</td>
<td>8</td>
<td>6</td>
<td>Yes</td>
</tr>
<tr>
<td>5/F/43</td>
<td>B</td>
<td>Goiter</td>
<td>TM</td>
<td>9</td>
<td>4</td>
<td>Yes</td>
</tr>
<tr>
<td>6/M/43</td>
<td>W</td>
<td>Prolonged intubation</td>
<td>SS, TM</td>
<td>7</td>
<td>1</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); SS, subglottic stenosis; TM, tracheomalacia.

**Table 2. Description of Stent Types and Stent-Related Complications**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Stent Type</th>
<th>Stent Duration, mo</th>
<th>Presentation</th>
<th>Stent Complication</th>
<th>Complete Stent Removal/No. of Attempts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CM</td>
<td>60</td>
<td>Recurrent bronchitis; dyspnea</td>
<td>Fracture</td>
<td>No/2</td>
</tr>
<tr>
<td>2</td>
<td>UM</td>
<td>24</td>
<td>Dyspnea</td>
<td>Granulation</td>
<td>Yes/2</td>
</tr>
<tr>
<td>3</td>
<td>CM</td>
<td>36</td>
<td>Dyspnea; chest pain</td>
<td>Fracture</td>
<td>No/3</td>
</tr>
<tr>
<td>4</td>
<td>CM</td>
<td>17</td>
<td>Dyspnea</td>
<td>Granulation</td>
<td>Yes/1</td>
</tr>
<tr>
<td>5</td>
<td>CM</td>
<td>6</td>
<td>Dyspnea</td>
<td>Granulation</td>
<td>Yes/2</td>
</tr>
<tr>
<td>6</td>
<td>UM</td>
<td>5</td>
<td>Dyspnea</td>
<td>Fracture</td>
<td>Yes/3</td>
</tr>
</tbody>
</table>

Abbreviations: CM, coated metal; UM, uncoated metal.
bronchitis and another complained of chest pain with respiration. The main stent-related complication was occlusive granulation tissue in 3 cases and stent fracture with malposition in 3 cases.

After presentation, all patients were examined using flexible bronchoscopy and found to have airway obstruction of 70% to 90% of the airway diameter (Figure 1). To maximize airway safety, a technique for combined endoscopic and open removal of the tracheal stent was instituted and performed in all patients. Patients were taken to the operating room, where anesthesia staff administered a light intravenous sedation. The first physician (M.B.G.) injected the midline neck with 5 to 10 mL of 1% lidocaine hydrochloride with 1:100 000 epinephrine to provide adequate local anesthesia. After preparing and draping, the neck was incised and a dissection was performed to the level of the tracheal rings. Excess neck fat and/or scarring was debulked in a controlled fashion. The trachea was not immediately opened because of the potential of cutting through the stent, but it was left fully exposed to provide rapid airway access and ventilation in the event of airway distress.

At this point, the patient was administered deeper sedation with spontaneous ventilation with midazolam hydrochloride and fentanyl citrate. A rigid, ventilating bronchoscope was passed into the trachea by a second physician (G.A.S.) to bring the occluding stent into view. The stent was then grasped with large alligator forceps and separated from the tracheal epithelium with a twisting motion and gentle traction to pull loose wire into the bronchoscope. Several passes with the forceps were generally necessary to remove the stents, which usually detached from the tracheal wall in piecemeal fashion (Figure 2). One polyurethane-coated metal stent was able to be removed as a single unit (Figure 3). Once the stent was removed from the anterior wall, a tracheostomy was performed. Additional stent material or larger balled-up pieces of stent that could not be removed via the bronchoscope could then be removed through the tracheostomy by passing a tracheal telescope and forceps directly through the tracheostomy incision. The procedure was completed once sufficient stent material was removed to allow placement of a No. 6 Shiley tracheostomy tube. Two patients experienced transient desaturations to 80% during the stent removal. No other complications were noted.

A second-stage procedure was performed several weeks later to allow maturation of the stoma site. To reduce the inflammatory response, patients were treated with a broad-spectrum oral antibiotic and an aggressive antireflux regimen of twice-daily proton-pump inhibitors and a bedtime histamine blocker and antireflux precautions during the intervening period. The second-stage procedure was again performed in the operating room, where additional rigid bronchoscopy was used to remove any remaining stent material, followed by placement of a silicone T-tube custom fit to span across the segment of collapse or stenosis. Five patients have successfully been treated with T-tubes for an average of 19 months (range, 6-30 months) and 1 patient with a standard tracheostomy tube for 40 months. The only observed T-tube-related complication was 2 separate episodes of peristomal cellulitis in 1 patient, which responded to oral antibiotics.

**COMMENT**

Benign tracheal stenosis is most commonly a complication of prolonged endotracheal intubation or tracheostomy. Approximately 16% of patients with prolonged intubation or tracheostomy develop lesions that occlude 20% or more of the airway. Prospective studies Prospective studies...
demonstrate concordant findings, noting tracheal stenosis to be present in 10% to 19% of patients undergoing prolonged intubation; however, the condition was symptomatic in only 1%. Although surgical resection with anastomosis has traditionally been the preferred treatment for benign tracheal stenosis, many conditions can increase the risk and reduce the effectiveness of surgery, such as poor overall health, extensive disease (>6 cm of trachea), certain inflammatory and infectious conditions, or patient refusal of surgery.2,4,20 In such cases, placement of a tracheal stent is a viable alternative to surgery.

The history of tracheal stenting began with the introduction of the Montgomery T-tube in 1964.1 The first Montgomery tube was an acrylic stent used during tracheal reconstruction to prevent postoperative stenosis.21 The inflexibility of the acrylic stent made it difficult to introduce into the airway; however, this problem was addressed with the production of single-piece silicone stents in 1965.21,22 As the name indicates, the Montgomery T-tube is a T-shaped tube with a vertical intraluminal portion and a horizontal portion designed to extend extracorporeally from the tracheostomy. The Montgomery T-tube’s primary advantages include minimal cough, minimal tissue reaction, preservation of normal respiration and phonation, and virtually no risk of migration secondary to the horizontal limb, anchoring the stent in place.21 Disadvantages include an external tracheostomy orifice and the potential for tube occlusion from dried mucus secondary to decreased mucociliary clearance of secretions. On the other hand, the horizontal limb of the device provides ready access to the airway for saline irrigation and suctioning.

Dumon2 developed a modified version of the Montgomery T-tube in the late 1980s by removing the extraluminal horizontal portion of that tube and adding a flange to prevent migration. The design was later changed to include a series of regularly placed struts to further hinder migration of the stent. Insertion of the stent requires general anesthesia and uses rigid bronchoscopy. Since 1990, more than 10,000 of these stents have been placed, making the Dumon stent the most widely used type today.19,23 The primary advantage of the Dumon stent is the lack of an external limb requiring tracheostomy; however, this modification has resulted in a significantly higher rate of stent migration and increased difficulty with retained secretions in certain patients compared with the Montgomery T-tube.

The widespread success of expandable metallic stents in vascular stenting during the 1990s led to the creation of metallic tracheal stents. Because of adverse effects associated with these stents, modern metallic stents are now constructed of a single thread of nitinol or stainless steel and are available in covered, partially covered, and uncovered versions. These stents have gained popularity in the treatment of both benign and malignant tracheobronchial obstruction because of the ability to place the stents with flexible bronchoscopy with the patient using local anesthesia with sedation. Compared with silicone stents, expandable metal stents demonstrate lower rates of migration, superior inner to outer wall–diameter ratio, decreased sputum retention, and better conforming to dynamic changes in airway diameter.3 However, these stents were noted to be extremely difficult to remove in the event of a stent-related complication or resolution of the underlying airway obstruction.4,6-8

Multiple studies have assessed clinical outcomes using different types of stents. Shin et al2 reviewed studies that assessed the complication rates for various types of plastic14,24,25 and metallic26,27 stents. All 163 patients who received a silicone stent for treatment of benign tracheal obstruction had immediate relief of symptoms. Common complications included sputum retention (16%), stent migration (10%), and granulation tissue formation (4%). In 54 of the 163 patients, these stents were electively removed after 18 to 32 months, and there was no recurrence in 80%. A total of 46 patients underwent placement of uncovered metallic stents.2 The most common indication for placement was lung transplantation, and the most common complication observed was stent fracture in 7 (15%) of 46 patients. Granulation tissue formation and stent migration were observed in 3 (7%) of 46 and 1 (2%) of 46 patients, respectively. These complications required stent removal in 4 (9%) of 43 patients.

Noppen et al13 performed a study in 39 patients who received 41 covered Ultraflex stents, 6 uncovered Ultraflex stents (Boston Scientific, Watertown, Mass), and 2 Wallstent stents (Schneider, Inc, Minneapolis, Minn). Stent removal was required in 10 (25.6%) of 39, with 8 (20.5%) requiring removal secondary to stent-related complications. Granulation tissue formation was noted in 17 (43.6%) of 39 patients, requiring stent removal in 5 (12.8%). Stent fracture that required removal occurred in 3 (7.7%) of 39 patients. In 2 (5.0%) of 39 patients, stents were removed secondary to tracheal healing and completion of treatment. Stents were removed via rigid bronchoscopy with the patient under intravenous general anesthesia. Ventilation and oxygenation were ensured via high-frequency jet ventilation. Stents were removed by grasping with a rigid alligator forceps, pulling the stent inside the lumen of the rigid bronchoscope while advancing its beveled end until the entire stent was inside the scope. If the stent fractured, the remainder was removed in a piecemeal fashion, a frequent feature of other studies. Tracheostomy was required in 2 patients because of “critical health status not amenable to other interventional or conservative treatments.”13(p485) No major complications from stent removal were noted.

Issues of tracheal stent placement have been widely addressed in the literature; however, few studies have assessed the best methods of stent removal. Such studies are clearly important, since up to 25% of patients receiving indwelling tracheal stents experience complications that require stent removal. The authors present a novel and safe approach for the removal of expandable metallic stents from the tracheobronchial tree, which has been performed in 6 patients without major complications. The conditions of 5 of the 6 patients have been maintained with Montgomery T-tubes with minimal complications. The conditions of 5 of the 6 patients have been maintained with Montgomery T-tubes with minimal complications after an average follow-up time of 23 months. Although expandable metal stents greatly improve the ability to treat small distal bronchial stenoses, the use of such stents in the trachea carry an increased risk of total airway obstruction and should therefore be used with caution only after ruling out other potentially safer options. Recently, the package in-
sert for self-expanding metal stents recommended that this product be placed in benign disease only as a last resort after all other treatment options have been exhausted. If the decision is made to use an expandable metallic stent, our experience is consistent with observations in the literature that covered metallic stents are usually easier to retrieve than uncovered stents in the event of a complication. Additionally, all 6 patients in the present series had signs and symptoms consistent with laryngopharyngeal acid reflux; therefore, it is imperative to assess for this condition in all patients with indwelling tracheal stents and to maximize medical and behavioral antireflux therapy when indicated.

In conclusion, increased use of expandable metallic tracheal stents will likely lead to increased rates of stent-related complications. The combined endoscopic and open stent removal technique maximizes airway safety during stent removal by offering a transtracheal route for ventilation and removal of stent debris. It also provides access for long-term management of the airway stenosis via a Montgomery T-tube. Given the limitations of current technology, the use of expandable metal stents in the trachea should be undertaken only as a last resort.

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Author Contributions: Drs Rampey, Silvestri, and Gillespie had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Rampey, Silvestri, and Gillespie. Acquisition of data: Rampey, Silvestri, and Gillespie. Analysis and interpretation of data: Rampey, Silvestri, and Gillespie. Drafting of the manuscript: Rampey, Silvestri, and Gillespie. Critical revision of the manuscript for important intellectual content: Rampey, Silvestri, and Gillespie. Statistical analysis: Gillespie. Administrative, technical, and material support: Gillespie. Study supervision: Silvestri and Gillespie.

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**REFERENCES**