Special article

Anesthesia and airway management for removing pulmonary self-expanding metallic stents☆

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Abstract The use of bronchoscopically placed self-expanding metallic stents (SEMS) and silastic stents in patients suffering from tracheobronchial stenosis or similar problems has proven to be an important clinical option. When complications occur, it may be necessary to remove the device. Removal of a SEMS is usually performed during general anesthesia with muscle relaxation and positive pressure ventilation, often using total intravenous anesthesia. Airway management depends on stent type and location. Intubating patients’ tracheas with a tracheal stent requires special caution, as it risks damaging tissue and dislodging the stent distally. Potential complications with removal include tracheal disruption, retained stent pieces, mucosal tears, re-obstruction requiring new stent placement, the need for postoperative ventilation, pneumothorax, damage to the pulmonary artery, and death.

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1. Introduction

During the last two decades, there has been considerable progress in the endoscopic management of central airway obstruction resulting from causes such as benign airway stenosis or neoplasia (Table 1). In particular, the use of silastic stents and self-expanding metallic stents (SEMS) placed bronchoscopically has provided important new clinical options [1]. These stents possess "memory" that allows them to return to their original shape after being compressed prior to placement in the airway. Upon deployment, the stent self-expands, although occasionally balloon inflation is required for complete expansion. Self-expanding metallic stents include the Gianturco-Z stent (Wilson-Cook Medical, Winston-Salem, NC, USA), the WALLSTENT (Boston Scientific Corp., Natick, MA, USA), and the Nitinol-based stents.

In lung transplant patients, complications such as anastomotic stenosis, malacia, or airway dehiscence are a common cause of morbidity and mortality that are now frequently addressed using a multimodality approach, including stent placement [2-4]. In many of these cases, maintenance of airway patency following stent placement results in substantial clinical improvement long after their deployment. Unfortunately, complications such as stent migration, stent fracture, mucous plugging, granuloma...
formation, and/or the formation of a false passage may occur. Whereas SEMS may cause excessive granulation, fracture, and, rarely, airway perforation, silastic stents are prone to migration, mucus plugging, and causing infections. When these complications are serious, it may become necessary to remove the stent [5].

We describe our experience providing anesthesia and airway management for the removal of pulmonary stents.

### 2. Technique of SEMS stent removal

Removing a SEMS can be very difficult, and has led to an FDA warning regarding their use in nonmalignant disease [6]. Removal is usually performed using rigid bronchoscopy in three basic steps. First, the degree of incorporation is assessed. Second, if possible, the stent is freed from the mucosa. Third, the stent is removed from the airway.

The basic method of stent removal involves the continuous controlled application of traction to the stent using alligator forceps (Figs. 1, 2, and 3). An instrument such as the barrel of the rigid bronchoscope or a Jackson dilator is often employed to help separate the stent from the airway wall before removal is attempted. In addition, the prior application of thermal energy via laser is sometimes helpful [7].

Nashef et al [8] reported their experience in removing 4 Gianturco stents endoscopically. "The removal technique is similar to that of rolling spaghetti on a fork, but much more difficult and at least equally messy. The procedure is

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**Table 1** Indications for stent placement in the tracheobronchial tree

<table>
<thead>
<tr>
<th>Indication</th>
<th>Benign</th>
<th>Malignant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Post-infectious: tuberculosis, histoplasmosis (fibrosing mediastinitis)</td>
<td>Extrinsic compression</td>
</tr>
<tr>
<td></td>
<td>Post-lung transplantation: anastomotic, segmental</td>
<td>Submucosal involvement</td>
</tr>
<tr>
<td></td>
<td>Post-inflammatory: Wegener’s granulomatosis, sarcoidosis, radiation</td>
<td>Following laser resection, electrocautery, photodynamic therapy, or cryotherapy to main airway patency</td>
</tr>
<tr>
<td></td>
<td>Post-intubation/tracheostomy</td>
<td>Tracheobronchial esophageal fistula (in conjunction with esophageal stent)</td>
</tr>
</tbody>
</table>

therefore time-consuming and often hindered by the well-embedded barbs. Removal may have to be piecemeal, requiring several fractures of the stent.

3. Potential complications of SEMS removal

Potential complications with removal are as follows: retained stent pieces, mucosal tears with or without bleeding, re-obstruction requiring new stent placement, the need for postoperative mechanical ventilation, pneumothorax, damage to the pulmonary artery, and death. When the stent is removed in pieces due to fracture during removal, it can lead to unwanted permanent incorporation of retained fragments in the tissue. In one report, critical airway obstruction occurred during removal of a welded tracheal stent using a rigid bronchoscope, and cardiopulmonary bypass had to be instituted urgently, with the stent being removed successfully by directly opening the trachea [9].

4. Anesthetic technique

Removal of a SEMS is usually performed with general anesthesia with muscle relaxation and positive pressure ventilation. An anesthetic technique that avoids inhaled agents prevents polluting the operating room with inhalational agents. Consequently, total intravenous anesthesia (TIVA) is usually used. The TIVA technique also ensures continuous delivery of anesthesia despite possible ventilation leaks around the rigid bronchoscope, movement in and out of the airway with the flexible bronchoscope, and/or utilizing intermittent apnea or jet ventilation techniques. When a pure propofol technique is used, it is usually delivered at a rate of between 50 and 150 mcg/kg/min. Remifentanil is more commonly added to the technique when a rigid bronchoscope or suspension laryngoscope is employed; typically in such cases, one mg of remifentanil is added to 500 mg of propofol and the propofol infusion is run between 50 and 100 mcg/kg/min with a corresponding remifentanil infusion rate between 0.1 and 0.2 mcg/kg/min. Note that the pharmacologic effects of the remifentanil helps to counter the hemodynamic effects (hypertension and tachycardia) from the suspension laryngoscopy or rigid bronchoscopy. Post-intubation muscle relaxation is usually achieved using rocuronium given in 10 mg increments, using a neuromuscular blockade monitor to guide administration.

5. Airway management

Airway management for SEMS removal depends on stent location. The most common method employs a rigid bronchoscope with the anesthetic circuit attached to the bronchoscope side port. Leaks around the rigid bronchoscope are common, but they can be easily overcome by packing the mouth with saline-soaked gauze. Special attention in removing all the gauze is needed to avoid subsequent airway obstruction from retained gauze pieces after removal of the bronchoscope.

In some cases where the stent is less incorporated in the mucosa, a non-rigid fiberoptic bronchoscope technique is possible. Here, intubation with a large diameter endotracheal tube (ETT; eg, size 8.5) cut short will make ventilation easier and will help make the fiberoptic bronchoscope easier to navigate. Intubating patients’ tracheas with a tracheal stent, whether a SEMS or a silastic type stent, requires special caution, as it risks dislodging the stent distally or causing other complications. In cases where the stent is high in the trachea, the laryngeal mask airway (LMA) can be advantageous, as it does not enter the glottis, although it provides a less definitive airway. Hung et al report a similar experience [10]. A suspension laryngoscope with intermittent apnea or jet ventilation, as well as a short, large-bore ETT via an existing tracheotomy with flexible bronchoscopy instruments, are good options. Each of these techniques requires clear communication between the anesthesiologist and the bronchoscopist. Issues of ventilation and oxygenation can be particularly problematic. It is usually necessary to maintain the oxygen concentration (FiO2) below 40% during thermal treatment with Nd:Yag lasers or endobronchial electrosurgery (EBES), while periods of extended apnea and complete airway obstruction can be expected during more challenging cases.
Complete airway occlusion frequently occurs during the critical phase of removing the stent or stent fragments. Therefore, it is always advisable to return to ventilation with 100% oxygen before stent extraction. Also, during thermal treatment, patients may not tolerate lower oxygen levels, and it may become necessary to defer treatment temporarily, and ventilate with higher oxygen levels.

In cases where incomplete extraction or stent fracture occurs, the bronchoscopist may wish to keep either Fogarty or wire-guided (eg, CRE™; Boston Scientific Corp., Natick, MA, USA) balloon dilators ready in order to facilitate dissection of the stent from the wall, re-open the airway lumen, or tamponade bleeding from airway tears. Again, use of such devices should prompt communication between anesthesiologist and bronchoscopist since it may lead to a need for high-pressure ventilation or apnea, depending on the location of the stent.

At the time of SEMS extraction, some potential pitfalls occur that are unique to flexible bronchoscopy. The most common problem is incomplete stent extraction or stent unraveling; as long as the stent is not cut with a laser or EBES, it can usually be removed in one piece. A few episodes in which the stent became stuck in the ETT and the flexible forces did not have the strength to pull it through the tube, have occurred. In these cases, the occluded ETT has had to be urgently removed and replaced.

6. Stent removal in lung transplant patients

Lung transplant patients present unique challenges with SEMS. Unless the patients are bilateral lung recipients, the stented bronchus may supply the only functional lung, and even a temporary loss of function may have dramatic consequences. Also, stent-related perforation into the pulmonary artery has been reported and may limit enthusiasm for removal unless absolutely necessary. The patient must be able to tolerate a pneumonectomy if this situation is suspected prior to consideration of SEMS extraction.

In lung transplant patients, rigid bronchoscopy may be unusually difficult since the mediastinum may be fixed following the transplant surgery. The left main-stem bronchus may be difficult to enter in these patients, and the right main-stem bronchus may be prone to dehiscence of the medial wall. If the SEMS was placed for dehiscence, it may be covered in excessive granulation tissue and not withstand rigid bronchoscopic techniques. The risk of infection is also very high due to the immunosuppression. Use of flexible bronchoscopy via an 8.5 ETT with rigid bronchoscopy for back-up is preferred. The stent is freed from all its attachments with forceps (Fig. 1). Balloon bronchoplasty is used to dissect the stent from the wall of the bronchus as much as possible; this minimizes mucosal trauma and chances of airway disruption and major bleeding (Fig. 2). The minimal use of laser, EBES, or argon plasma coagulation treatment, or pretreatment with cryotherapy, preserves stent integrity as long as possible. To remove the stent, a large rat-toothed forceps is used to grasp opposing sides of the stent so as to allow for a more uniform tension to minimize unraveling (Fig. 3).

7. Removal of silastic stents

Like SEMS, silastic stents may also require repositioning or removal. Because silastic stents have a relatively smooth outer surface, their anchorage into the airway wall tends to be superficial, and as a result stent migration is common. However, this also means that removal of silastic stents, where needed, tends to be easier than the removal of SEMS-type stents, which often become embedded into the airway to varying degrees. Silastic stent placement, manipulation, and removal is best achieved using a rigid bronchoscope.

In conclusion, removing tracheobronchial stents is a meticulous, risky process that is not without potentially serious complications. It requires careful planning and execution from all parties involved. In particular, the anesthesiologist must be nimble in planning an airway management strategy and reacting to changing conditions. Finally, discussions between bronchoscopist and anesthesiologist concerning each step of the procedure are particularly important in dealing with these complex airway cases.

References