A 62-year-old male with a diagnosis of subglottic and tracheal stenosis resulting from a prolonged intubation was scheduled for a laser bronchoscopy and placement of a silicon T-shaped tube. His history was significant for two myocardial infarctions, an episode of congestive heart failure and exertional angina. A 6 mm polyvinyl chloride endotracheal tube, wrapped with aluminum tape, was placed in an existing tracheostomy stoma. During the course of the procedure, a sudden bright flash occurred followed by an explosive noise and black smoke rising in the anesthesia circuit and from the patient's mouth. The endotracheal tube was removed and the patient was treated for first and second degree burns in the supraglottic area and base of the tongue.

In laser surgery of the airway, special care should be given to reducing the flammability of the inspired gases which can be best accomplished by the mixture of helium with oxygen. Helium acts to retard ignition of polyvinyl chloride tubes in concentrations of 60% or greater. The external surface of the tube can also be protected with the application of a metallic tape affixed in a spiral fashion. Finally, a protocol for the management and treatment of this emergency should be adopted and rehearsed.

Introduction

This case report illustrates a situation where a carbon dioxide (CO₂) laser ignited an endotracheal tube, wrapped with aluminum tape, during a laser bronchoscopy. Strategies for the prevention and management of laser initiated endotracheal fires will be discussed.

A 62-year-old male with a diagnosis of subglottic and tracheal stenosis was scheduled for a laser bronchoscopy with the placement of a T-tube (a silicon T-shaped tube which serves as a tracheal stent and a tracheostomy tube.) Three years previously, the patient suffered complications as a result of a myocardial infarction requiring prolonged endotracheal intubation. The patient developed tracheal stenosis and subsequently a tracheostomy was placed. Approximately one year later, the patient experienced a second myocardial infarction and an episode of congestive heart failure which was treated medically. Since that time he reported experiencing exertional angina approximately three times a week.

Preoperative examination revealed a patient in no acute distress, with a patent metal tracheostomy in place. A cardiac catheterization six months previous to the scheduled procedure demonstrated three-vessel coronary artery disease, mild mitral valve regurgitation and ventricular hypokinesis with an ejection fraction of 39%. The remaining physical examination was within normal limits. The preoperative chemistries, hematology and chest x-ray results were within normal limits. The preoperative ECG demonstrated an incomplete right bundle branch block. A room air arterial blood gas revealed the following: pH 7.41, PaO₂ 98 and PaCO₂ 34. The patient's medications included digoxin 0.2 mg, nitroglycerin ointment and nitroglycerin tablets as needed for angina.
The patient was taken to the operating room and routine monitors were applied. Anesthesia was induced with sodium pentothal and fentanyl citrate and maintained with pancuronium and isoflurane in 100% oxygen. A 6 mm cuffed polyvinyl chloride (PVC) endotracheal tube, wrapped with aluminum tape distal to the pilot balloon tube insertion and proximal to the cuff, was passed through the tracheostomy stoma (Figure 1). The cuff was inflated with sterile saline solution. The larynx was exposed using a suspension laryngoscope and a laser bronchoscope was positioned.

The operation proceeded uneventfully until the sudden occurrence of a bright flash in the surgical field, followed by an explosive noise and black smoke rising from the mouth of the patient and through the expiratory limb of the anesthesia circuit (Figure 2). The endotracheal tube, with the cuff intact, and the bronchoscope were immediately removed. The patient was reintubated with a new tube and the surgical procedure aborted. Breath sounds revealed scattered mild rhonchi. The arterial blood gas within five minutes of the event was pH 7.43, PaO$_2$ 445 and PaCO$_2$ 35; dexamethasone 8 mg and cefazolin 2 gm were administered intravenously.

The anesthetic was maintained with isoflurane, pancuronium and 100% oxygen while a bronchoscopy was performed revealing no apparent subglottic thermal injury. However, first and second degree burns were observed in the supraglottic area and the base of the tongue. Emergence from anesthesia was uneventful with the patient’s endotracheal tube being replaced with a tracheostomy tube at the conclusion of the case. The patient was admitted to the postanesthesia care unit in no apparent distress. A postoperative chest x-ray in the anesthesia recovery area was unremarkable. The patient was admitted to the intensive care unit for overnight observation.

Subsequent postoperative examinations, while hospitalized and following discharge from the hospital, demonstrated normal healing without complication. Closer examination of the endotracheal tube, following the incident, revealed a localized perforation through the aluminum tape, proximal to the intact cuff (Figure 3).

The use of the laser (light amplification of stimulated emission of radiation) as a surgical adjunct has become popular since its introduction in the 1960s. When planning for the anesthetic management of laser surgery with general anesthesia, there are two major considerations the practitioner must address: (1) the flammability of gases, and (2) the protection of the endotracheal tube from ignition. These two points will be dealt with separately.

**Avoidance of flammable gases**
In the presence of a high-intensity thermal laser beam, the selection of a nonflammable, nonexplosive anesthetic agent appears obvious. The commonly used inhalational agents (isoflurane, enflurane and halothane) are considered nonflammable. The principal clinical dilemma arises when select-
ing the appropriate concentration of oxygen to use since an enriched oxygen atmosphere can foster the ignition of the endotracheal tube.

In a study by Hirshman and Smith, PVC, red rubber and silicon endotracheal tubes were exposed to various combinations of oxygen and nitrous oxide to determine if any combination of these gases were less flammable.\textsuperscript{1} With the carbon dioxide laser set at 15 watts for a 0.1-second duration and directed at the tip of each endotracheal tube, it was noted that each tube ignited with flows of 100% oxygen, 100% nitrous oxide or any combination of the two. When oxygen alone was directed through the endotracheal tubes, a concentration of 30% vigorously supported combustion, 25% weakly supported combustion, but at 21% oxygen, the tubes failed to ignite.\textsuperscript{1} This study suggested that the inspired oxygen concentration should be reduced to the lowest safe level, preferably at or around 25% before the laser is used.

Since nitrous oxide supports combustion as well as oxygen, the combination of both gases is not recommended.\textsuperscript{2,3} Many of the anesthetic machines in operation today will not deliver an oxygen concentration of 25%, therefore, oxygen must be diluted with room air, nitrogen or helium to effectively reduce flammability.\textsuperscript{3}

Recently, Pashayan and associates revealed that unwrapped PVC endotracheal tubes were less subject to ignition when a mixture of helium (an inert gas) and oxygen was directed through the tube rather than a nitrous oxide or nitrogen in oxygen mixture.\textsuperscript{7} Because of its high thermal diffusivity, helium acts as a heat sink and retards ignition of the endotracheal tube.\textsuperscript{6} In concentrations greater than or equal to 60%, helium delayed ignition of plain (unmarked) PVC tube segments for at least 20 seconds with a continuous 10-watt laser beam. The radio-opaque, barium sulfate strip found on most PVC tubes ignited much sooner.\textsuperscript{7} Pashayan did note, however, that when oxygen concentrations greater than 40% were used, fire did occur. The author recommends that when higher than 40% concentrations of oxygen are required, laser resection should be discontinued until concentrations can be reduced to 40% or less.\textsuperscript{7}

**Protection against endotracheal tube ignition**

One of the most serious incidences that can occur during laser surgery is fire. This is especially true in laser surgery of the airway as was the case in this report. The incidence of endotracheal tube fires has been reported to be as high as 1.5% in patients undergoing laryngeal surgery with the carbon dioxide laser.\textsuperscript{4,5,6} An endotracheal tube can be ignited in two ways: by direct impact of the laser beam, as in the present case report (Figure 2), or by indirect ignition of burning material next to the tube.\textsuperscript{3,10} Presently, all commercially available endotracheal tubes, with the exception of metal tubes, will ignite when struck by laser in an enriched oxygen environment.\textsuperscript{3,4,11-13}

Studies by Ohashi and associates compared the time elapsed for the ignition (amount of energy needed to ignite a fuel) and combustion (ability of a fuel to sustain a flame) of PVC and silicon endotracheal tubes. The tubes were exposed to a continuous laser beam of five watts with a mixture of oxygen and nitrous oxide flowing through them at a rate of five liters per minute.\textsuperscript{11} He found that the PVC tube ignited as early as eight seconds upon exposure and combustion occurred within 26 seconds. The silicon tube neither ignited nor supported combustion above 120 seconds. Therefore, silicon would be considered less flammable than the PVC tube.\textsuperscript{11}

In separate studies by Schramm and Meyers, comparing heat tolerance of red rubber and PVC endotracheal tubes, they found that although red rubber tubes may melt and burn, the temperature required is significantly higher than the one required to melt PVC endotracheal tubes and, thus, would present a safer choice.\textsuperscript{14,15}

Several attempts have been made to cover the external surface of the endotracheal tube with different materials. Patel and associates suggested wrapping the tube in moistened commercially available muslin and keeping it wet during the operation.\textsuperscript{16} Major disadvantages include the need to keep the wrapping material constantly wet during the procedure, bulkiness and the risk of ignition should drying occur.\textsuperscript{8} Kumar recommended coating the tube with dental acrylic. However, the acrylic coat makes the tube rigid, does not prevent ignition and is awkward to use.\textsuperscript{17} The most popular method of protecting the endotracheal tube from ignition is with the application of aluminum or copper foil tape. The technique of wrapping the endotracheal tube with self-adhesive foil tape was first described by Snow and associates.\textsuperscript{18} He found that red rubber tubes completely wrapped with the tape were resistant to ignition with oxygen concentrations up to 50%.

Proper selection and application of the metallic tape is paramount to its effectiveness. Some commercially available tape has the aluminized surface on the back layer of the tape so the laser beam has to pass through a clear layer of plastic compound before encountering the reflective surface. The use of this tape should be avoided.\textsuperscript{4}

Sosis laser tested and compared five commercially produced tapes. He discovered that copper foil tape and 3M Company tape number 425 pro-
vided excellent protection of the endotracheal tubes and urged their use during carbon dioxide laser surgery of the airway. He also noted that tape width of 0.5 to 1.0 cm made application easier. Once the proper tape is selected, meticulous attention to application is required. The tape should be applied in a spiral, overlapping fashion beginning proximal to the tip or cuff and ending high on the tube where laser misdirection is minimal (Figure 1).

Care should be taken to avoid rough edges and gaps when wrapping the tube in order to minimize trauma to the laryngeal mucosa and exposure of underlying endotracheal tube to the laser. Although the cuff of the endotracheal tube cannot be protected by the metallic tape, it is nonetheless vulnerable to laser penetration and should not be neglected. The cuffs of all tubes should be filled with either water or saline to allow them to absorb more energy before they rupture. Then, if the laser does penetrate the cuff, the liquid within the cuff will help extinguish any fire.

**Recommendations for management of an endotracheal fire**

Personnel present during an explosion of fire tend to be paralyzed by the mental shock of the event. Therefore, to avoid any delay in management of this emergency, the operating room team should be familiar with a practical protocol for the management of such an event.

**Initial management**

**Explosion.** It is imperative that the ignited tube be disconnected from the breathing system and immediately removed as was done in this case report. This is probably best done by the operating surgeon or the anesthetist. The products of combustion (heat, smoke and toxins) can result in injury to the tracheobronchial tree. Furthermore, collapse of the distal tip of the tube can occur producing respiratory obstruction. Fragments of the tube and metallic tape may also break off and become a loose foreign body in the airway.

**Ventilation.** Following extubation, the patient should be mask ventilated with 100% oxygen until reintubation with a smaller size endotracheal tube can be accomplished. The smaller tube size is suggested to facilitate the ease of intubation in the event of airway edema. In addition, Schramm and associates advise against discontinuation of the anesthetic in order to expedite the evaluation and management of the emergency. He advocates the administration of narcotics and a muscle relaxant. In the case study, the anesthetic was continued with pancuronium and isoflurane in 100% oxygen.

**Evaluation**

After the patient's airway has been reestab-

lished and the condition stabilized, the tracheobronchial tree should be evaluated. Direct visualization by rigid bronchoscopy will allow for assessment of tissue injury and the removal of any large foreign bodies from the airway. The trachea and mainstem bronchi should be lavaged with saline solution to remove as much carbon material as possible without causing additional injury.

Once accomplished, a flexible bronchoscopy should be performed to evaluate and extract fine foreign bodies from distal airways. Finally, the larynx and pharynx should be visualized and examined by direct laryngoscopy. Location and extent of injury are noted and any foreign bodies are retrieved.

**Early management**

Once the extent of laryngopharyngeal injury is defined, a plan for management is developed. Management may include tracheostomy and assisted ventilation in moderate to severe burns or extubation in those with minor injury not involving the larynx. Consideration should be given to the possibility of laryngeal edema which could develop in the early postoperative period; thus, early extubation could have a deleterious result.

All patients will require supplemental humidified oxygen of 30% to 60% in the postoperative phase. Humidification is needed due to the loss of mucociliary function and a tendency for mucous plugs to form and for secretions to inspissate. In those injuries requiring postoperative ventilation, positive end expiratory pressure (PEEP) may be necessary to maintain adequate arterial oxygenation and to help decrease the tendency of atelectasis due to the loss of surfactant. In the early management phase, serial arterial blood gases are necessary to evaluate the adequacy of alveolar gas exchange and guide the practitioner in ventilation management.

Management beyond this point may vary but could include corticosteroids, bronchodilators and antibiotics. Corticosteroids, like dexamethasone used in the case report, have been recommended for the treatment of both smoke inhalation and the bronchospasm produced by the smoke or heat. Bronchospasms may be treated with steroid or nonsteroid inhalants or intravenously with aminophylline. These may be necessary, along with PEEP, to decrease bronchospasm or alveolar hypoventilation. Finally, prophylactic antibiotics are recommended with the initial choice being ampicillin or cephalosporin. Daily cultures or tracheobronchial secretions will further specify subsequent antibiotic therapy.

**Subsequent early management**

Once the patient is in the postanesthesia care
unit, ventilatory care should continue with humidified oxygen and other indicated therapies. The patient should have a chest x-ray to assess pulmonary damage and arterial blood gases as necessary. Even if no significant damage is suspected, admission to the intensive care unit for observation is recommended. Any further treatment will depend on the extent of the injury and the clinical condition of the patient.

**Conclusion**

A case report of an explosion during laser surgery of the upper airway was presented with a step-by-step protocol for managing airway explosions outlined in Table I. The incidence of tube ignitions is as high as 1.5% in patients undergoing laser surgery of the larynx. Practitioners managing such cases should have a protocol immediately available and should be rehearsed for the management of this potentially devastating event. Of critical importance is the cooperation of the anesthesia and surgical teams to minimize risk to the patient and to decrease the duration of the patient’s exposure to the destructive effects of such an explosion. The individual steps of the protocol will differ slightly according to each patient’s needs, but the overall approach outlined is useful for treating most burns of this type.

**REFERENCES**


**AUTHOR**

George G. DeVane, CRNA, MHS, received his BSN from the University of North Carolina at Greensboro and his anesthesia certificate from the Medical University of South Carolina in Charleston, where he also received his master’s degree in Health Sciences. He is currently a graduate instructor and the clinical coordinator in the Department of Nurse Anesthesia Education at the University of Kansas Medical Center, Kansas City, Kansas.

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**Table I: Management of endotracheal fires**

<table>
<thead>
<tr>
<th>Step</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Simultaneously stop ventilation, disconnect endotracheal tube from breathing system and remove the endotracheal tube.</td>
</tr>
<tr>
<td>2</td>
<td>Mask ventilate with 100% oxygen.</td>
</tr>
<tr>
<td>3</td>
<td>Reintubate with a smaller size cuffed or uncuffed endotracheal tube, or ventilating bronchoscope.</td>
</tr>
<tr>
<td>4</td>
<td>Maintain anesthetic to facilitate injury assessment.</td>
</tr>
<tr>
<td>5</td>
<td>Rigid bronchoscopy should be performed to remove large foreign bodies and carbon debris and then lavage the trachea with saline solution.</td>
</tr>
<tr>
<td>6</td>
<td>By flexible fiberoptic bronchoscopy, visualize small airways, remove small distal foreign bodies and lavage distal airways with saline solution.</td>
</tr>
<tr>
<td>7</td>
<td>Use direct laryngoscopy and pharyngoscopy to evaluate airway and remove fragmented mucosa.</td>
</tr>
<tr>
<td>8</td>
<td>Obtain arterial blood gases to assess alveolar gas exchange.</td>
</tr>
<tr>
<td>9</td>
<td>Administer steroids (8 mg dexamethasone intravenously in the adult).</td>
</tr>
<tr>
<td>10</td>
<td>Administer antibiotics (1 gm of ampicillin or cephalosporin intravenously in the adult) if no contraindications exist.</td>
</tr>
<tr>
<td>11</td>
<td>Provide a high-humidity environment, and leave the patient intubated with ventilatory support if laryngeal edema is a potential hazard.</td>
</tr>
<tr>
<td>12</td>
<td>Check chest x-ray for pulmonary damage.</td>
</tr>
<tr>
<td>13</td>
<td>Provide for observation in the intensive care unit regardless of the degree of injury.</td>
</tr>
</tbody>
</table>