Objectives

At the conclusion of this PBLD, the participant will be able to:

1. Understand the implications of:
   a) electrocautery
   b) skin preparation solutions
   c) airway fires on patient outcome.

2. Learn the preventive measures and treatment strategies that can be employed to improve perioperative outcome from these burning issues.

Introduction

Currently, there are no public records of operating room fires; however, based on anecdotal evidence, approximately 20-100 operating room fires are thought to occur each year. The incidence of operating room fires has decreased in recent years due to the use of non-flammable inhaled anesthetics and increased awareness.

For a fire to occur, three components must be present: a) an oxidizer b) fuel source c) ignition mechanism.

Oxidizers in the OR include oxygen and nitrous oxide. An oxidizer-enriched environment can exist if there is a closed or semi-closed circuit, or it can be created if there is trapping of an oxidizer (i.e., oxygen trapped under drapes near the face when using a nasal cannula)
Examples of ignition sources include electrocautery, lasers, drills and burrs, fiberoptic cables and defibrillator pads.

Examples of fuel sources include endotracheal tubes, sponges, drapes, gauze, alcohol-containing solutions, hair, and gowns.

**Scenarios in which OR fires may occur**

**Case #1**: 67 year old (69 inches, 124 kg) male scheduled for triple endoscopy with laser vaporization of a lesion on the left true vocal cord.

1. **Any concerns about the procedure?**

2. **Any patient specific concerns?**

   **PMH**: Diabetes Mellitus, Obstructive Sleep Apnea (home CPAP), Morbid Obesity, Hypertension, Atrial Fibrillation
   **PSH**: Uvulopalatopharyngoplasty, Appendectomy

3. **How would you proceed?**

   Following pre-oxygenation, anesthesia was induced with propofol, rocuronium and fontanel. Bag mask ventilation was difficult and required a two-handed technique. Direct laryngoscopy with a MAC 3 yielded a Grade IV view and a 6.0 single-cuffed laser endotracheal tube (Medtronic laser-shield II) resulted in an esophageal intubation. The ETT was removed, and bag mask ventilation resumed since the patient rapidly desaturated with SpO2 in the low 80’s. Once the patient’s saturation was greater than 96%, direct laryngoscopy was repeated with a MAC 4 yielding a Grade III view and the ETT was successfully placed in the trachea.

   The endotracheal tube’s cuff was filled with air during the triple endoscopy and then replaced with saline before the laser vaporization.

3. **Any recommendations? What are alternatives to the current anesthetic plan?**

   It was noted that whenever ventilation was interrupted (i.e., disconnecting the circuit to move the operating room bed) the patient would rapidly desaturate which would necessitate recruitment maneuvers. Ventilator settings were assist-control, tidal volume 600-650, PEEP 12cm H2O, respirator rate 12 and PIP 38 cm H2O with
FiO2 ranging from 0.5-0.9 during to keep SpO2 >92%. Anesthesia was maintained with desflurane. Tube ignition occurred roughly 45 minutes into the procedure. The ventilator was turned off, field was flooded with saline and the surgeon removed the endotracheal tube. Surgeon was unable to re-intubate or pass an intubating stylet, so a laryngeal mask airway was placed and SpO2 remained 90-92% while an emergent tracheotomy was performed. Rigid bronchoscopy was then performed to remove debris from the trachea.

Discussion

What is the mechanism of combustion?

Combustion occurs when the laser penetrates the endotracheal tube and then causes the ignition of the tube. Combustion is facilitated by the heat produced by the laser, the flow of oxygen and combustible materials (i.e., endotracheal tube).

What is the role of FiO2?

In this case, FiO2 was kept between 0.5-0.9 during the procedure to maintain adequate oxygenation. When combustion occurred, the FiO2 was 0.5% in 5.2% desflurane. Since the FiO2 was greater than room air (0.21) an oxidizer-enriched atmosphere was present. Oxidizers present in the operating room include are oxygen and nitrous oxide. Since a correlation
exists between a high level of inspired oxygen and tube combustion, it is prudent to keep FiO2 as low as possible to adequately oxygenate the patient.

What are strategies to reduce the incidence of airway fire?

1. Decreasing the flammability of the endotracheal tube.
   a. All endotracheal tubes are flammable. PVC tubes are very sensitive to CO2-laser energy and appear to be more easily ignited by CO2 lasers and release more toxic compounds when ignited. Red rubber tubes are also very sensitive to combustion, but they supposedly produce the less toxic compounds when ignited.
   b. Metal endotracheal tubes. Currently there are 2 metal endotracheal tubes commercially available and are approved for use only with specific lasers. The Laser Flex Tube (Mallinckrodt, Inc.) is an airtight stainless steel spiral with two distal inflatable PVC cuffs. The tubes is resistant to CO2 and KTP laser energy, but not Nd:YAG laser. Secondly, there is the Bivona Fome-Cuf (Bivona Inc.). This is an aluminum spiral tube with an outer silicone covering and a self-inflating foam-filled cuff that is deflation resistant; it is only approved for use with CO2 pulse lasers.
   c. Wrapping the tube in either aluminum foil with adhesive backing, copper foil with adhesive backing or plastic tape with metal coating on one side and adhesive on the other. Lead foil is toxic and should never be used. Taping does not provide protection against combustion of the inflatable cuff of the tube, but do offer protection against inadvertent laser hits of the tube shaft.

2. Jet Ventilation or Intermittent Extubation
   a. Jet ventilation using a metallic jet ventilation cannula or intermittent extubation with our without apnea can improve safety since these techniques remove flammable material from the airway during laser.

3. Reduction of the available oxygen content (FiO2) to the minimum required for reasonable arterial saturation.

What should you do in the event of an airway fire?
According to the American Society of Anesthesiologists’ Practice Advisory on the prevention and management of operating room fires (Anesthesiology, 2008) immediately:

1. Remove the endotracheal tube
2. Stop all flow of airway gases
3. Remove all sponges and other flammable material from the airway
4. Pour saline into the airway

Once the fire has been extinguished, resume ventilation by mask and anesthesia should be continued. Direct laryngoscopy and rigid bronchoscopy can be performed to inspect the airway and assess mucosal damage as well as to remove debris. If the fire was an “internal blowtorch” bronchial lavage may be necessary followed by repeated bronchoscopy to remove debris. If there is any airway damage, the patient should be re-intubated. Depending on the extent of airway damage, a tracheotomy may be necessary.

Lastly, the patient’s face, and oropharynx should be examined and a chest radiograph performed. Pulmonary damage due to heat or smoke inhalation is an indication for mechanical ventilation and may result in prolonged intubation. High-dose corticosteroids are suggested.
OPERATING ROOM FIRES ALGORITHM

Fire Prevention:
- Avoid using ignition sources\(^1\) in proximity to an oxidizer-enriched atmosphere\(^2\)
- Configure surgical drapes to minimize the accumulation of oxidizers
- Allow sufficient drying time for flammable skin prepping solutions
- Moisten sponges and gauze when used in proximity to ignition sources

Is this a High-Risk Procedure? An ignition source will be used in proximity to an oxidizer-enriched atmosphere
- Agree upon a team plan and team roles for preventing and managing a fire
- Notify the surgeon of the presence of, or an increase in, an oxidizer-enriched atmosphere
- Use cuffed tracheal tubes for surgery in the airway; appropriately prepare laser-resistant tracheal tubes
- Consider a tracheal tube or laryngeal mask for monitored anesthesia care (MAC) with moderate to deep sedation and/or oxygen-dependent patients who undergo surgery of the head, neck, or face.
- Before an ignition source is activated:
  - Announce the intent to use an ignition source
  - Reduce the oxygen concentration to the minimum required to avoid hypoxia\(^3\)
  - Stop the use of nitrous oxide\(^4\)

Fire Management:
Early Warning Signs of Fire\(^5\)
- Fire is not present; Continue procedure
- HALT PROCEDURE Call for Evaluation
- FIRE IS PRESENT

AIRWAY\(^6\) Fire
- IMMEDIATELY, without waiting
  - Remove tracheal tube
  - Stop the flow of all airway gases
  - Remove sponges and any other flammable material from airway
  - Pour saline into airway

NON-AIRWAY Fire
- IMMEDIATELY, without waiting
  - Stop the flow of all airway gases
  - Remove drapes and all burning and flammable materials
  - Extinguish burning materials by pouring saline or other means

If Fire is Not Extinguished on First Attempt
Use a CO\(_2\) fire extinguisher\(^7\)
- If fire persists: activate fire alarm, evacuate patient, close OR door, and turn off gas supply to room

- Re-establish ventilation
- Avoid oxidizer-enriched atmosphere if clinically appropriate
- Examine tracheal tube to see if fragments may be left behind in airway
- Consider bronchoscopy

- Maintain ventilation
- Assess for inhalation injury if the patient is not intubated

Fire out
Assess patient status and devise plan for management

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\(^1\) Ignition sources include but are not limited to electrocautery units and lasers.

\(^2\) An oxidizer-enriched atmosphere occurs when there is any increase in oxygen concentration above room air level, and/or the presence of any concentration of nitrous oxide.

\(^3\) After minimizing delivered oxygen, wait a period of time (e.g., 1-3 min) before using an ignition source. For oxygen dependent patients, reduce supplemental oxygen delivery to the minimum required to avoid hypoxia. Monitor oxygenation with pulse oximetry, and if feasible, inspired, exhaled, and/or delivered oxygen concentration.

\(^4\) After stopping the delivery of nitrous oxide, wait a period of time (e.g., 1-3 min) before using an ignition source.

\(^5\) Unexpected flash, flame, smoke or heat, unusual sounds (e.g., a "pcp," snap or "fomp") or odors, unexpected movement of drapes, discoloration of drapes or breathing circuit, unexpected patient movement or complaint.

\(^6\) In this algorithm, airway fire refers to a fire in the airway or breathing circuit.

\(^7\) A CO\(_2\) fire extinguisher may be used on the patient if necessary.
**Case #2:** A 40-year-old male weighing 375 pounds was admitted with chronic obstructive pulmonary disease and respiratory failure. He was scheduled to have a tracheotomy for prolonged ventilatory support.

1. **What are your concerns in this particular case?**

   Morbid obesity is a concern. Due to the patient’s body habitus, the surgeon may have difficulty during dissection and creating the tracheotomy. Additionally, factors related to COPD and morbid obesity may make ventilation challenging.

   Tissue dissection was difficult; approximately 10cm of adipose tissue needed to be dissected in order to locate the trachea. During the dissection, there was subcutaneous bleeding and fat that needed to be cauterized.

   The tracheotomy was approached in the usual fashion; however, there was bleeding near the tracheotomy site. Again, cautery was used to control the bleeding. There was sudden airway fire noticed at this time.

2. **What would you do in this situation?**

   The endotracheal tube was quickly disconnected from the anesthesia machine. Attempts were made to extinguish the fire using the drapes and manual pressure. A bowl of sterile saline was poured over the persistent flame. This extinguished the flames. The wound was quickly sucked dry.

   The endotracheal tube cuff was evaluated for any rupture. It was intact. The tracheotomy tube was inserted without any further complication and the surgery was completed uneventfully.

3. **At this time would you like to proceed with any further exam?**

   A flexible bronchoscopy was performed to evaluate the airway for any burns. The airway was found to be intact with no mucosal injury.

4. **What do you think caused fire in this particular case?**

   Due to the patient’s COPD and respiratory failure, the minimum FiO2 needed to avoid hypoxia was 50%. This increased FiO2, coupled with the cauterization of subcutaneous fat could have contributed to fire in our case. Cautery can lead to the build up of flammable/explosive compounds which can then ignite and cause a fire. It is well known that gases arising from diathermies fat will burn when made hot enough or if mixed with sufficient oxygen.
5. Why is that the tracheotomy related airway fires are relatively minor and often non fatal?

The three elements of an airway fire are the fuel (e.g. endotracheal tube, drapes, swabs, alcoholic solutions, vaporized adipose tissue), a source of oxygen (e.g. oxygen, nitrous oxide) and heat (diathermy, laser, static electricity, hot light bulb). During a tracheotomy, unlike other airway surgeries, these three elements can usually be kept quite separate from one another and so this operation is not generally considered to carry a high fire risk.

6. What would you have done differently in this case?

Let us explore this in the form of fire triangle.

**Oxygen:**

The use of cautery could have been avoided. The inhaled oxygen concentration could not be decreased in this case because of the patient’s respiratory condition. Since the endotracheal tube was not damaged, the fuel source was likely the adipose tissue. Both these factors suggest that if cautery could have been avoided, the airway fire might have not occurred.

Helium has been suggested to be a better combination with oxygen instead of nitrogen as it reduces the likelihood of ignition.

**Endotracheal tube:**

Silicon/metallic Laser Shield endotracheal tube (Xomed, Jacksonville, USA) was the only endotracheal tube not to be ignited by electrocautery. It is essential that only cuffed endotracheal tubes be used during a tracheotomy to prevent oxygen from leaking into the zone where the incision is made in the trachea. A further precaution is to inflate the tracheal cuff with saline. This can prevent ignition should the cuff be punctured by diathermy.

**Heat:**

Cutting, coagulation and blend modes of diathermy are all known to have caused airway fires. In practice, the risk of diathermy causing an airway fire before the tracheal incision is minimal if a cuffed endotracheal tube is in situ. Obtaining a meticulously dry field prior to opening the airway is imperative. The trachea should be incised with a scalpel, scissors or harmonic (ultrasonic) knife. There is no reason to use diathermy to incise the trachea; it is a fire hazard and diathermy is neither efficient in cutting through calcified tracheal rings nor effective at preventing bleeding from the mucosa. Cutting mode diathermy is particularly hazardous as it generates higher temperatures than coagulation mode. Even coagulation mode on a low-power setting is known to have caused two fires and
cannot be recommended. Some authors recommend bipolar diathermy as a safer alternative. The risk of ignition is still present since some arcing or sparking at the electrode-tissue interface is possible. Unfortunately, the dangers associated with diathermy appear not to be widely appreciated.

**Recommendations:**

- All OR staff should be educated that an airway fire may occur during tracheotomy.
- A bowl of saline should be available at all times during the procedure.
- A fire extinguisher should be immediately available. In practice, a carbon dioxide fire extinguisher will be the usual choice.
- Have a self-inflating ventilation bag (e.g. Ambu bag) available in case it becomes necessary to ventilate the patient with room air.
- Do not use nitrous oxide or any of the flammable/explosive anesthetic agents.
- Use a single-lumen endotracheal tube which is long enough to allow the tip to be advanced to the carina (the carina is approximately 24-25 cm from the teeth in an average male).
- Use saline to inflate the endotracheal tube cuff. Make sure there is no leak of anesthetic gases past the endotracheal tube cuff.
- Use the lowest Fi02 in either nitrogen (air/oxygen mixture) or helium that provides adequate arterial oxygenation.
- If the tracheotomy wound is significantly deep (e.g. in an obese patient), use a suction device to dear any build up of diathermy products from within the wound.
- Before the trachea is opened, advance the endotracheal tube down the trachea so the tip is close to the carina in order to minimize the likelihood of damage to the cuff when the trachea is incised.
- Consider using a fiber-optic bronchoscope to position the tip of the endotracheal tube close to the carina. If the tube is too short, consider changing it for a longer one.
• Control all bleeding points and obtain a meticulously dry operative field. Incise the trachea using a scalpel, scissors or a harmonic knife. Never use diathermy to cut through the trachea.

• Once the trachea has been opened and the surgeon is ready to insert the tracheotomy tube, stop ventilating, deflate the endotracheal tube cuff and withdraw the endotracheal tube carefully under direct vision until the tip is just above the tracheal hole (do not remove the tube completely at this stage). Be prepared to push the endotracheal tube back down the trachea to secure the airway if there are any difficulties encountered while inserting the tracheotomy tube.

• If bleeding occurs once the trachea has been incised, first ensure that the airway is secured with either a tracheotomy or endotracheal tube with the cuff inflated. If there is cuff leak from the trachea, then temporarily stop ventilation and ligate or suture. If unavoidable, use bipolar diathermy while using suction to clear oxygen and products from the wound. Consider pushing damp swabs into the wound to occlude any air leak. Once the tracheotomy tube is secure in the trachea, inflate the tracheotomy tube cuff and suck out the tube using a suction catheter, checking that the suction catheter passes easily through the whole length of the tube. If this is satisfactory, then commence ventilation through the tracheotomy.

• In the event of fire, immediately disconnect the patient from the anesthesia machine, switch off the anesthetic gas flow, disconnect the gas pipelines and ventilate with room air using a self-inflating bag.

• Use an airway filter if there is smoke in the OR. Extinguish the fire. Consider flushing saline down the endotracheal tube to extinguish any intraluminal fire.

• Consider removing or changing the tube to minimize both the inhalation of toxic products of combustion and the spread of fire into the tracheobronchial tree. However, changing the endotracheal tube may be more risky than leaving it in if the patient was a difficult intubation or if the airway has become edematous.

• **Prevention is the key.**
References