Laser and Airway Fire

- Fires in operating room are a potential hazard to patients and operating room staff
- Although rare (estimated ~550-650 surgical fires occurring in the United states out of 65 million operations done in 2009), when happened it could cause serious morbidity and mortality (airway fire in particular)
- Operating theatre staff (surgeons, anaesthesiologists and nurses) should have adequate alertness and awareness of this potential problem, and formulate plans to deal with OR fire

![Fire Triangle Diagram]

Fig.1: The “fire triangle” showing the 3 necessary components for combustion
Potential injuries that can be produced by operating room fire

- Thermal injury
  - To skin and mucosa – partial-thickness or full-thickness burns, predispose to fluid and electrolyte loss, heat loss and infection
  - To airway – life-threatening airway obstruction
- Toxins released from burning plastics can also lead to inhalational injuries and/or asphyxiation
  - E.g. hydrogen, chloride, cyanide, phenols, aldehydes, other complex hydrocarbons
  - HCl produced by burning PVC ETT
- Carbon monoxide

Figure 2. Demonstration of rocket-like flames shooting from a tracheal tube caused by laser ignition of the tube with 100% oxygen flowing. Image provided courtesy of ECRI Institute.
Laser and head & neck surgery

- Commonly involving sharing of airway
- Fuel (e.g. ETT) + ignition source (e.g. laser) + oxidizer (e.g. O₂ enriched environment) = high risk for operating room fire!
- In order to minimize risk of airway fire, operating room staff must make an effort to avoid putting the 3 components of the fire triangle close together

![Image](image.png)

Figure 4. Rigid bronchoscopic view of Nd:YAG laser application for a bulky airway malignancy.

Fuel

- Is an ETT required?
  - Alternative ventilatory strategies:
    - Spontaneous ventilation
    - Supreglottic jet ventilation
    - Infraglottic jet ventilation
    - Intermittent apnoea
- If ETT is required
  - Metallic tape for wrapping ETT (however none of the metallic tapes are made for endotracheal tube wrapping and none are approved by FDA for this use; the cuff of tube remains vulnerable to the effects of laser)
  - Laser-resistant ETT*
  - Metal tracheostomy cannula
- *Examples of laser-resistant ETT:
  - Mallinckrodt Laser-Flex (available in QMH)
  - Xomed Laser-Shield II
  - Sheridan Laser-Trach endotracheal tube
  - Rusch Lasertubus endotracheal tube
- Note: charred tissue and laser plume can also ignite in an oxygen-rich environment!
Examples of devices developed to prevent laser-induced surgical fires

Laser-Flex endotracheal tube: has a crimped stainless steel shaft, 2 PVC cuffs arranged in series; the purpose of having 2 cuffs is that the distal cuff remains intact even if the proximal one is damaged by laser; the proximal balloon is filled with methylene-blue + saline for easier detection of possible leak or perforation, while the distal balloon is filled with saline; intended for use with CO₂ and KTP lasers (uncuffed tube #3 – 4.5mmID; cuffed tube #4.5 – 6mmID);
The applicability of these recommendations must be considered individually for each patient.

At the Start of Each Surgery:
- Enriched O₂ and N₂O atmospheres can vastly increase flammability of drapes, plastics, and hair. Be aware of possible O₂ enrichment under the drapes near the surgical site and in the fenestration, especially during head/facial/neck/upper-chest surgery.
- Do not apply drapes until all flammable preps have fully dried; soak up spilled or pooled agent.
- Fiberoptic light sources can start fires: Complete all cable connections before activating the source. Place the source in standby mode when disconnecting cables.
- Moisten sponges to make them ignition resistant in oropharyngeal and pulmonary surgery.

During Head, Face, Neck, and Upper-Chest Surgery:
- Use only air for open delivery to the face if the patient can maintain a safe blood O₂ saturation with supplemental O₂.
- If the patient cannot maintain a safe blood O₂ saturation without extra O₂, secure the airway with a laryngeal mask airway or tracheal tube.
- Exceptions: Where patient verbal responses may be required during surgery (e.g., carotid artery surgery, neurosurgery, pacemaker insertion) and where open O₂ delivery is required to keep the patient safe:
  - At all times, deliver the minimum O₂ concentration necessary for adequate oxygenation.
  - Begin with a 30% delivered O₂ concentration and increase as necessary.
  - For unavoidable open O₂ delivery above 30%, deliver 5 to 10 L/min of air under drapes to wash out excess O₂.
  - Stop supplemental O₂ at least one minute before and during use of electrosurgery, electrocautery, or laser, if possible. Surgical team communication is essential for this recommendation.
- Use an adherent incise drape, if possible, to help isolate the incision from possible O₂-enriched atmospheres beneath the drapes.
- Keep fenestration towel edges as far from the incision as possible.
- Arrange drapes to minimize O₂ buildup underneath.
- Coat head hair and facial hair (e.g., eyebrows, beard, mustache) within the fenestration with water-soluble surgical lubricating jelly to help isolate from nonflammable agents.
- For coagulation, use bipolar electrosurgery, not monopolar electrosurgery.

During Oropharyngeal Surgery (e.g., tonsillectomy):
- Scavenge deep within the oropharynx with a metal suction cannula to catch leaking O₂ and N₂O.
- Moisten gauze or sponges and keep them moist, including those used with uncuffed tracheal tubes.

During Tracheostomy:
- Do not use electrosurgery to cut into the trachea.

During Bronchoscopic Surgery:
- If the patient requires supplemental O₂, keep the delivered O₂ below 30%. Use inhalation/exhalation gas monitoring (e.g., with an O₂ analyzer) to confirm the proper concentration.

When Using Electrosurgery, Electrocautery, or Laser:
- The surgeon should be made aware of open O₂ use. Surgical team discussion about preventive measures before use of electrosurgery, electrocautery, and laser is indicated.
- Activate the unit only when the active tip is in view (especially if looking through a microscope or endoscope).
- Deactivate the unit before the tip leaves the surgical site.
- Place electrosurgical electrodes in a holster or another location off the patient when not in active use (i.e., when not needed within the next few moments).
- Place lasers in standby mode when not in active use.
- Do not place rubber catheter sheaths over electrosurgical electrodes.
Risk factors for fire in operating room

**Ignition sources**
- Electrosurgical unit (ESU)
- Lasers
- Extreme heat source (e.g. fiberoptic light source)

**Flammable materials**
- Ointments and solutions (e.g. alcohol-based skin preps, paraffin oil)
- Patient sources (e.g. hair, GI gases)
- Surgical materials (e.g. drapes, dressings)
- Equipment
  - Anaesthetic: ETT, face masks, suction catheters, LMAs...
  - Surgical: wound drains, tubings, packing materials...

**Oxidizer**
- Oxygen-enriched environment
  - Endotracheal tube, operative field...
- Nitrous oxide

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Laser and airway fire

Surgical lasers
- Second most common ignition source in operating room fires
- Frequently serious

What is laser?
LASER stands for Light Amplification by Stimulated Emission of Radiation
- Laser radiation is monochromatic, coherent, collimated with high energy density
- Surgical lasers are able to provide high amount of energy to a precise location
- Operates in either continuous mode or pulsed mode
- Excellent tools in providing haemostasis at a precise location
- Relative lack of trauma to healthy tissues
- Reduces postoperative pain and edema

Common types of surgical laser
1. CO₂ laser
   - Infrared radiation with wavelength 10.6μM
   - Makes precise cuts, provides excellent haemostasis with little collateral damage
   - Readily absorbed by water, blood and all biologic materials independent of pigmentation
   - Acts via thermal injury and vaporizing cells
   - Can be absorbed by glass and plastic – cannot be transmitted through traditional fiberoptics
2. Holmium:yttrium-aluminum-garnet (Ho:YAG) laser
   - Pulsed infrared output with wavelength 2.1μM
   - Excellent absorption in water-rich tissues
   - Used in nasal surgeries and tonsillectomies
3. Neodymium (Nd):YAG laser
   - Emits radiation with wavelength 1064nm
   - Highest tissue penetration of all currently available medical lasers
   - Can be transmitted via traditional fiberoptics
   - Well suited for haemostasis by coagulation and shrinking lower airway tumours
   - Can cause generalized thermal damage and delayed edema with tissue sloughing
4. Potassium titanyl phosphate (KTP) laser
   - Contains Nd:YAG laser which the frequency is doubled by passing the beam through KTP crystal
   - Wavelength 532nm, readily absorbed by blood
   - Smaller spot diameter and better haemostasis than CO₂ laser
Surgical preps and drapes
- Many of the surgical prepping agents are flammable (esp. alcohol-based ones)
- One should always allow adequate time for the liquid preparations to evaporate and fully dry before draping (drying process may take up to 5 minutes!)
- Towels used to absorb dripped preparation solution should be removed
- Avoid pooling, spilling or wicking of flammable liquid preparations
- Wet material (e.g. saline soaked gauze) may dry out fairly rapidly and hence increase the risk of fire

Ignition source
- Always limit the laser output to the lowest clinically acceptable power density and pulse duration
- Test fire the laser before starting the procedure (if using through an endoscope, test fire before inserting the endoscope into patient)
- Laser should be placed in standby mode when not in active use
- Deactivate laser and place in a standby mode before removing it from the surgical site
- Laser should be activated only by the person using it and only when the tip is in direct view
- Use surgical devices designed to minimize laser reflectance and use a laser backstop to reduce the likelihood of tissue injury distal to the surgical site
- Never clamp the fibers to the drapes (may break the fibers)
- When performing lower airway surgery, the laser fiber tip should always be visible and clear of the end of the bronchoscope or ETT before using it

Oxidizer
- Always try to limit the oxygen concentration to less than 30%
- Prevent any possible leak around the ETT with either a cuffed ETT or spontaneous ventilation through LMA
- If oxygen concentration greater than 30% is used, the oropharynx should be suctioned with a metal cannula before using laser / electrosurgical unit
- *During tracheostomy, use oxygen concentration lower than 30% before entering the trachea; if possible, always use a scapel or scissors rather than electrosurgical unit or electrocautery instruments to make the tracheal incision
Laser-Trach endotracheal tube: constructed from red rubber and embossed with copper foil to diffuse laser energy.

Wrapping of ETT with laser-resistant material (e.g. aluminium foil); e.g. Laser-Shield II endotracheal tube.

Lasertubus endotracheal tube: made of soft white rubber covered by a protective layer of microcorrugated silver foil and absorbent Merocel sponge around the distal 17cm of tube; a dual cuff-within-cuff system.
EMERGENCY PROCEDURE
EXTINGUISHING A SURGICAL FIRE

Fighting Fires ON the Surgical Patient
Review before every surgical procedure.

In the Event of Fire on the Patient:
1. Stop the flow of all airway gases to the patient.
2. Immediately remove the burning materials and have another team member extinguish them.
   If needed, use a CO₂ fire extinguisher to put out a fire on the patient.
3. Care for the patient:
   — Resume patient ventilation.
   — Control bleeding.
   — Evacuate the patient if the room is dangerous from smoke or fire.
   — Examine the patient for injuries and treat accordingly.
4. If the fire is not quickly controlled:
   — Notify other operating room staff and the fire department that a fire has occurred.
   — Isolate the room to contain smoke and fire.
Save involved materials and devices for later investigation.

Extinguishing Airway Fires
Review before every surgical intubation.

At the First Sign of an Airway or Breathing Circuit Fire, Immediately and Rapidly:
1. Remove the tracheal tube, and have another team member extinguish it. Remove cuff-protective devices and any segments of burned tube that may remain smoldering in the airway.
2. Stop the flow of all gases to the airway.
3. Pour saline or water into the airway.
4. Care for the patient:
   — Reestablish the airway, and resume ventilating with air until you are certain that nothing is left burning in the airway, then switch to 100% oxygen.
   — Examine the airway to determine the extent of damage, and treat the patient accordingly.
Save involved materials and devices for later investigation.

More information on surgical fire prevention, including a downloadable copy of this poster, is available at www.ecri.org/surgical_fires