1 Safety Concerns

AIRWAY SAFETY WITH LASER AND CAUTERY USE

Common Sites of Operating Room Fires

- 34% airway
- 28% head or face
- 38% elsewhere on or inside patient

An oxygen-enriched atmosphere was a contributing factor in a majority of cases.

Methods to Protect the Patient

If using a nasal cannula during a procedure involving a laser or cautery:

- Drapes should be arranged to avoid trapping high concentrations of O_2 within them.
- Placing a suction catheter under drapes helps to pull trapped exhaled gases away.

When using a laser or cautery in the airway:

- All lubricants used in the airway should be a water-soluble type.
- Use an oxygen/air combination that includes the minimum O_2 concentration needed to support clinically acceptable arterial saturation (30% or less).
- Do not use nitrous oxide—it is combustible.

Endotracheal Tubes, Circuit Tubing, and Fire Prevention

A polyvinyl chloride (PVC) endotracheal tube (ETT) is highly flammable. Specific laser-retardant ETTs (flexible metal laser ETTs) should be used during oral, tracheal, or esophageal laser procedures that require supplemental oxygen.

Filling the endotracheal balloon with saline can help to put out any fire or spark that arises. Alternatively, the balloon can be filled with a mixture of saline and methylene blue to indicate if the balloon's patency has been compromised at any time during the surgery. Also employ the following precautions:

- Metallic wrap around a PVC endotracheal tube
- Tape around the patient's mouth or face—3M Blenderm (paper and adhesive tape can ignite)
- Breathing circuit—covered with foil and wet towels
- Saline-soaked pledgets—can be placed around the ETT for an airway laser procedure
- Bottle of sterile water—kept at the work area to extinguish any fire if it occurs

Minimizing Oxygen Concentration in the Field

Oxygen and nitrous oxide vastly increase the flammability potential of a surgical area. Even air supports combustion, albeit to a lesser degree. Use an air/O_2 combination in ignition-prone cases; avoid the use of nitrous oxide.

Keep the FiO_2 as low as possible. If the patient's oxygen saturation falls, notify the surgeon, who can stop the laser. Increase the FiO_2 and manually ventilate the patient to increase the saturation level. The surgeon can begin to use the laser again when the FiO_2 is back down to 30%.

Low flow of oxygen is better than higher flow; use the lowest required concentration of inspired oxygen. Concentrations of oxygen greater than 21% are considered "enriched."

When using oxygen prongs during facial surgery performed under local anesthesia, the surgeon may instruct the anesthetist to turn off the oxygen, and wait at least 60 seconds for the oxygen to dissipate before using the cautery unit. The oxygen flow can be resumed when the electrical surgical unit (ESU) is no longer needed. Regulating the oxygen at the lowest setting that keeps the patient's oxygen saturation at a safe level is recommended; usually 2 to 3 liters per minute is usually all that is needed. Stop oxygen flow at least 1 minute before the use of an ESU, if possible.

You can "blend" the gases with this nasal cannula setup—that is, an adaptor is placed at the end of the circuit, allowing a nasal cannula to be connected (see Figure 1-1). You can dial in a percentage FiO_2 with this system. Whatever method you choose, make sure you have a safe delivery of the oxygen/air mixture to the patient in an "oxygen-enriched environment." You do not need to use the nasal cannula outlet for these cases.

Not using oxygen supplementation except for rescue is used by many institutions, depending on the patient's ASA status and the level of sedation needed for the procedure. Let the surgeon know if you cannot maintain an oxygen saturation level that is greater than 92%.

If oxygen is needed by the patient, it is generally safe to place the prongs in the patient's mouth when operating on the upper face. The tubing should be taped to keep it in place.

Extreme vigilance must be maintained to be sure the prongs stay in place so that oxygen never blows openly over the field. If it does, there is a risk of igniting a fire on the patient's face.

In summary, be aware of possible oxygen enrichment (the accumulation of oxygen or nitrous oxide) under the drapes near surgical site, especially during head and neck surgery (from the nipples up). Arrange drapes (tenting to allow room air circulation and avoid oxygen trapping) to minimize oxygen buildup underneath; put suction tubing under the

Figure 1-1 *Nasal Cannula*

drapes to suction excess flow. Also, maintain lower flows of oxygen, if it is needed at all. With an outlet around the drapes, gravity will assist in pulling oxygen to the floor away from the patient.

Management of Airway Fires

The mnemonic DIVER can help you remember the steps in managing an airway fire. At the first sign of a tracheal tube, rapidly take the following actions:

Disconnect the breathing circuit from the tracheal tube and extubate the patient. Disconnect the O_2 source at the Y-piece and remove burning objects from airway (i.e., remove the ETT, ensuring that the entire tube is removed).

Irrigate the site with water if fire is still smoldering.

Ventilate the patient by mask or reintubate; deliver the lowest possible O_2 concentration.

Examine the patient's mouth and oral cavity. **E**valuate the injury by bronchoscope and laryngoscopy, looking for burns in the trachea and bronchial tree; remove foreign bodies and debris.

Reintubate or manage the patient accordingly.

ELECTROCAUTERY: ELECTRIC SURGICAL UNIT (ESU)

Electrocautery is the process of burning or cutting through tissue by using a small probe (the ESU) with a radio-frequency electrical current running through it. It has become a popular surgical tool for cutting or coagulating away unwanted tissue and slowing or stopping hemorrhage.

Types of Electrocautery

In **monopolar ESU** (also known as unipolar ESU), the active electrode is the surgical site; the current passes through the patient to a collecting electrode or a dispersive plate (placed somewhere else on the patient's body), thereby completing the electrical circuit back to its source. The energy is then returned to the generator.

An argon beam coagulator (unipolar ESU) uses a stream of argon gas to support the electric current, which avoids charring of the instrument tip. This technique was developed to effectively control large amounts of bleeding in surgery. The flow of gas blows away debris from the surgical field and produces a more uniform coagulated surface with less smoke. Thus surgeons are able to stop bleeding faster.

Bipolar ESU uses two electrodes that look like forceps; a dispersive pad and collecting electrode are unnecessary because the energy flows from one tine of the forceps to the other (completing the electrical circuit), passing through the patient's tissue as it flows. The energy is then returned to the generator. This technique, which uses less energy than unipolar ESU, is used mostly of ophthalmic surgery and neurosurgery.

Fire Hazards Associated with ESU

The ESU is a common OR ignition source. The same cautions and procedures to prevent surgical/airway fires for laser surgery are applicable to the ESU.

With an ESU, the cautery tip is heated to a temperature of several hundred degrees Fahrenheit; the unit produces heat by concentrating electric current at the tip of the electrode.

Characteristics of the ESU

- The ESU operates by generating megahertz frequency currents (radio-frequency range) of anywhere from 500,000 Hz to more than 1 million Hz.
- Voltage is as high as 3000 volts.
- An ESU can produce nearly 400 watts of power.
- Heat is produced at the tip to cauterize a blood vessel or cut tissue.
- Energy is focused on small area. Current enters the patient, is dispersed through a grounding pad, and must complete a circle back to the

unit. Current will seek to return through other conductors (patient or surgeon) if a dispersive plate or grounding pad is not properly placed.

Correct Placement of a Grounding Pad

- Close to the operative site
- As far away as possible from the EKG pads
- In conjunction with adequate gel and sufficient skin contact
- Not placed over scar tissue, hair, or implants

Injuries with ESU

Skin burns are a potential hazard when ESU is used. They can result from problems with the following elements:

- Return-plate connection—must cover a large area so that the current density is below a level that will cause burns
- Inadequate or improper application of the pad
- Disruption of the return wire—newer units have a double return wire with impedance monitoring
- Insufficient conductive gel (dry dispersive plate)
- Wet patients—from electrolyte solution or blood; may form electrical contacts with equipment

Nitrous oxide and oxygen are both highly flammable. Use a mixture of oxygen and air if the ESU is in use.

ESU and Pacemakers

ESUs can reprogram pacemakers or automatic implantable cardioverter-defibrillator (AICD) units or cause microshock. To avoid these problems:

- Place the pad below the thorax.
- Have equipment (magnet, external pacemaker, and defibrillator) and drugs ready for an emergency.

The AICD may interpret the ESU signal as an arrhythmia and trigger a defibrillation, thereby causing ventricular tachycardia and ventricular fibrillation. Given these potential problems, an AICD should be deprogrammed (by a technician) prior to the patient undergoing an elective procedure.

FIRES AND BURNS IN THE OPERATING ROOM

Communication with the surgeon and surgical team is *essential* to prevent fires! If a laser or cautery is used, have a bottle of normal saline or water nearby to use in case of a fire. Three elements are required to have a fire:

- An ignition source (heat): electrocautery, lasers, static electricity, fiberoptic sources, defibrillators. (Primarily under the control of the surgeon.)
- A fuel source: hair, skin, body tissue, intestinal gases, chemicals, endotracheal tubes, drapes, sheets, gown, towels, sponges. (Primarily under the control of the OR personnel.)
- A source of oxygen (oxidizer): oxygen and nitrous oxide vastly increase flammability; medical air and ambient air are also oxidizers. (Primarily under the control of the anesthesia provider.)

Common Operating Room Ignition Sources

- Electric surgical unit (68%)
- ESU grounding pad
- Lasers (13%)
- Static electricity
- High-intensity fiberoptic light source (Tip temperature is well above the ignition temperature of most surgical drapes.)
- Argon beam coagulator
- Defibrillator paddles—if used incorrectly
- Heated IV fluids, lights or compresses, warming blankets—can cause thermal injuries

Methods to Protect Patients from Ignition Sources

- Keep the cautery tip in its holder.
- Turn off the fiberoptic light source when it is not in use; do not set it down when it is turned on.

- Do not fire defibrillator paddles into open air.
- Do not use a warming blanket hose without the warming blanket.

Common Operating Room Fuel Sources

- Drapes
- Hair
- Intestinal gas
- Skin prep solutions (especially alcohol based)

Water-based preps such as Betadine, Soloprep, and Pharmaseal contain no alcohol and are considered nonflammable. A water-soluble lubricant (K-Y Jelly) should be used instead of petrolatum on the surgical field because it is not flammable.

Preps such as iodophor (Duraprep) and chlorhexidine digluconate (Hibitane) contain alcohol but in an aqueous solution, which is less flammable.

Any solution labeled "tincture" by definition is suspended in alcohol and is, therefore, extremely combustible. Benzoin, Mastisol, and merthiolate (Thimerosal) all contain alcohol. These dangerously flammable solutions should be used with the utmost caution in the OR. Petroleum jelly (Vaseline) and petroleum-based ointments can ignite in the presence of oxygen. Caution is also advised when using other materials that are flammable, such as degreasers (acetone and ether), aerosols, paraffin, and wax.

Methods to Protect Patients from Fuel Sources

- Do no drape the patient until all flammable prep fluids have fully dried.
- Use fire-retardant surgical drapes.
- The prepping solution should be applied with minimal dripping to avoid forming pools of liquid on, under, or around the body. Any pools that do form, especially in the umbilicus and cricoid notch, should be blotted. Allow thorough drying of applied solutions (this may take 2 to 3 minutes or as long as 10 minutes) before draping, and ensure dissipation of alcohol vapors before using any heat source near the patient. A completely dry prep ensures that potentially flammable ethanol vapors from alcohol-based preparations will not be trapped beneath the drapes. Only then can an ESU or laser be used without fear of igniting the alcohol.
- Avoid petroleum-based compounds near an ignition source.
- Keep drapes and the patient's skin moist (but not with prepping solutions) around surgical site.
- Protect hair near the surgical site by coating it with Surgilube or K-Y Jelly (water-based gels).
- Have the patient wash his or her hair before the procedure to remove any hairspray.

Common Operating Room Oxygen Sources

Oxygen and nitrous oxide vastly increase the flammability of the surgical area. Even air supports combustion, albeit to a lesser degree. Use an air/O_2 mixture in ignition-prone cases; avoid the use of nitrous oxide.

Methods to Protect Patients from Oxygen Sources

Minimize the oxygen concentration in the surgical field. Keep the FiO_2 as low as possible. If the patient's oxygen saturation falls, notify the surgeon, who can stop the laser. Increase the FiO_2 and manually ventilate the patient to increase the saturation level. The surgeon can begin to use the laser again when the delivered FiO_2 returns to 30%.

A low flow of oxygen is better than a higher flow; use the lowest required concentration of inspired oxygen. Concentrations of oxygen greater than 21% are considered "enriched."

Types of Fire Extinguishers

Class A (*ash*): for wood, paper, cloth fires

Class B (*boils*): grease, flammable liquid fires

Class C (*current*): electrical fires

ABC: Dry chemical, fights all types of fires

Carbon dioxide (CO_2): used for Class B and C fires; doesn't leave a harmful residue

Surgeries in Which Fires Commonly Occur

- Bowel surgery with bowel gas ignition. To protect against this type of fire, vent the bowel before entering it surgically, and do not enter the bowel with an ESU.
- Oropharyngeal surgery. To protect against the risk of fire, use moist sponges to pack the patient's throat and fill ETT balloon with blue-dyed water.
- Tracheostomy. The tracheal tube can catch on fire when an ESU is used to enter the trachea. To protect against this risk, use a fire-resistant ETT tube, monitor the surgical method used to enter the trachea, and be extremely vigilant about recognizing an airway fire if an ESU is used.

Fire On a Patient in the Operating Room (Oxygen-Enriched Environment): What You Do

1. Remove what is burning to protect against direct burns.
2. Smother any remaining flames or extinguish the fire with water or saline if an electrical source is not involved. If electrical equipment is involved, do *not* attempt to extinguish it with water or saline; instead, disconnect the power source and use a Class C fire extinguisher.
3. Turn off all oxygen sources.
4. Alert others to start the fire plan.
5. Rescue the patient from danger, and move him or her to a safe area.
6. Provide medical treatment as required.
    - Control bleeding.
    - Deal with further injuries.

MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging (MRI) is based on absorption and emission of energy in the radiofrequency range of the electromagnetic spectrum.

MRI Safety Considerations

There are three main problem areas in MRI:

- Magnetic field
- Radio frequency (potential for heating and burns; use reinforced anode ETTs and PA catheter thermistor wires to reduce this risk)
- Time-varied magnetic fields

Other difficulties may be related to the MRI unit's noise level, which should not exceed 140 db. Also, although MRI is not considered hazardous to a fetus, caution is recommended when using this imaging modality during the first trimester of pregnancy.

Metal Objects

A "missile effect" occurs when MRI is used in the presence of metal objects because the static magnetic field has the capacity to attract ferromagnetic objects. Everyone entering the area should be questioned and asked to remove the following items:

- Purse, wallet, money clip, credit cards, cards with magnetic strips
- Electronic devices (e.g., beepers or cell phones)
- Hearing aids
- Metal jewelry, mechanical watches
- Pens, paper clips, keys, coins
- Hair barrettes, hairpins
- Any article of clothing that has a metal zipper, buttons, snaps, hooks, underwire, or metal threads
- Shoes, belt buckles, safety pins

Foreign bodies are contraindicated in an MRI because they could create a health hazard. This includes *any* ferromagnetic electronic, magnetic, or mechanically activated implants that have the possibility of moving in the body once the patient is inside the MRI machine. Examples include a neurostimulator, AICD, pacemaker, catheter with metal components (poses a risk of burn injury), aneurysm clip, implanted infusion pump, or cochlear implant. The risk depends on the possibility of movement and dislodgment in the body. X-rays should be done first if the patient's body is suspected to contain any metal.

Transfer the patient into the MRI suite with an *aluminum* oxygen tank. Brass pipes hold tubing and circuits that are used to pass through MRI wall into control room.

RADIATION

Radiation is used extensively in the operating room, such as in fluoroscopy, portable X-ray, and radiation implants. Because lead absorbs X-rays, healthcare providers are advised to protect themselves from radiation by wearing a lead apron and thyroid shield.

The occupational limit of radiation exposure is mandated to be less than 5000 mrem (roentgen-equivalent for man) or 50 millisieverts (mSv) annually. The occupational limit of exposure for pregnant women is 500 mrem (5 mSv). The unit dose of equivalence is based on the absorbed dose (radiation absorbed dose [RAD]), where 1 milliroentgen (mrem) = 1/1000 rem.

Sources of Radiation Exposure

- Flat films: One chest X-ray = 25 mrem to patient
- Routine angiography: approximately 8000 mrem
- Fluoroscopy with video display: may be greater than 75,000 mrem; amount depends on long the beam is on
  - X-rays can be scattered and reflected from surfaces.
  - Backward scatter occurs in the direction opposite that of the gun.

The dose of radiation received may be reduced by moving approximately 6 feet away; being 6 feet away from the X-ray source is equivalent to the protection from wearing a 0.5-mm-thick lead sheet.

The intensity of any radiation is inversely proportional to the square distance from the source: Double the distance and cut the exposure by 75%. The farther away you are from the X-ray, the better protected you are.