AANA Journal Course

Update for nurse anesthetists

3

*6 CE Credits

Eliminating surgical fires: A team approach

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The incidence of surgical fires is rising. One agency estimates that the frequency of surgical fires is comparable to that of wrong-site surgery with an incidence of 50 to 100 fires annually. Anesthetists must assist in the development and implementation of processes that eliminate the disfiguring or deadly results from surgical fires. Understanding the 3 components of fires—heat sources, fuels, and oxidizers—is essential to reduce or eliminate the risk of surgical fires. This AANA Journal course discusses the need for a clearly formulated plan, rehearsing a response to fires in or on the patient, and clearly designated prevention parameters. As part of the surgical team, the vigilance and dedication of nurse anesthetists can lead the efforts to prevent adverse outcomes from surgical fires.

Key words: **ECRI recommendations, fire triangle, surgical fires.**

Objectives:

At the completion of the course, the reader should be able to:

1. Recognize the most common fire locations and the 3 major components that contribute to fires in the operating room.
2. Identify safety processes to reduce the incidence of fires.
3. Explain how reaction planning and training will reduce fires and the severity of patient injury in a fire.
4. Describe methods to educate the operating room team on the dangers of surgical fires.
5. List anesthesia-controlled issues and items that could reduce the frequency of surgical fires.

Historical review

Since the elimination of flammable anesthetics, training about the dangers of fire has almost disappeared. That decrease in education may contribute to the increase in operating room (OR) and surgical fires. An OR fire is any fire that occurs in the OR—not necessarily one that involves a patient. A surgical fire is burning of materials *on or in* a surgical patient. Ignition of surgical drapes, dermatome glue, or an endotracheal tube (ETT) are examples of surgical fires. As part of our responsibility as practitioners caring for our patients, we must address this clinical challenge.

In 1997, the Federal Emergency Management Agency estimated that 20 to 30 fires occur each year in the OR.[1] The actual incidence of surgical fires is unknown because there is no central or required reporting system.[2] California, Tennessee, and Washington require reporting of all OR and surgical fires.[3] However, ECRI (formerly the Emergency Care Research Institute), a not-for-profit health research agency, believes the frequency of surgical fires is comparable to that of other surgical mishaps such as wrong-site surgery. ECRI estimated in 2003 that at least 50 to 100 surgical fires occur annually. Of these surgical fires, 10 to 20 result in litigation.[4]

On June 24, 2003, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) published Issue 29 of the Sentinel Event Alerts, addressing the need for vigilance and the prevention of surgical fires.[5] It used the research done by the ECRI and identified that the most common ignition sources were electrosurgical equipment (68%) and lasers (13%). The most common fire location was the airway (34%), and an oxygen-enriched environment was a contributing factor in 74% of all cases. The head and neck account for 28% of fire locations; other sites on the body represent 38%.[3,5,6] In July 2003, the JCAHO announced preventing surgical fires as a potential national patient safety goal.

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In late 2003, Abbott Laboratories advised health care professionals by letter of their investigation of reports of fire in the respiratory circuit of anesthesia machines when sevoflurane was the inhalational agent in use.[7] The location of these surgical fires supports the assessment made by ECRI and reinforced by the JCAHO Sentinel Events Alert.

The fire triangle

Fires always involve 3 components: (1) fuels, (2) a source of combustion (heat), and (3) oxygen. Controlling these 3 elements can prevent or extinguish a fire. Each member of the operating team *usually* has primary responsibility for one of these factors: the OR personnel provide the fuels, the surgeon provides a source of combustion, and the anesthesia providers control the oxygen-enriched environment (Table).

• *Fuels.* Fuels are from obvious and less-than-obvious sources. Obvious sources include oral topical anesthesia sprays, anesthesia breathing circuits, ETTs, nasal cannulas, and plastic masks. Gauze sponges, disposable or reusable drapes, catheters, alcohol-based prep agents, pools of prep solution and their evaporating vapors, tincture of benzoin, povidone iodine (Betadine) solutions, dermatome glue, silicone endobronchial stents, and synthetic sutures are also culprits. Human adipose tissue, muscle, lanugo, connective tissue, gastrointestinal gases, bladder gases, and debris on active electrosurgical electrodes are less obvious fuel sources in the OR. [8-14]

• *Ignition sources.* There are a number of heat sources in the OR. A heat source must get hot enough to ignite the fuel material. Lasers are a particularly dangerous source of combustion because they create intense heat that burns through anything in their path. The power output of the laser light, the length of pulse duration, the presence of blood or tissue residue, and the distance of the laser probe from the fuel all affect time to ignition. Reflected laser beams can start fires in unanticipated locations in the OR. Monopolar and bipolar electrosurgical units and argon beam coagulators produce heat for the purpose of controlling surgical bleeding. It takes only 451°F to ignite paper, but the temperature of an electrocautery device can reach 1,500°F. The focused beam of a halogen light source and sparks from carbide burrs, grinders, and defibrillators are additional heat sources that require our attention. Fiberoptic light sources transmit heat from the light source to the end of the fiberoptic cable. If the cords are not connected correctly from the source, the escaping light is intense enough to serve as an ignition source in or around the surgical field.[14,15]

• *Oxidizers.* Medical-grade oxygen is the most obvious source of additional oxygen in the OR. However, nitrous oxide also can support combustion, and the fires can be as severe as those in 100% oxygen. Bowel gas and nitrous oxide combine to make a highly explosive mixture that is easily ignited by an electrosurgical device. The use of oxygen in open breathing systems can easily raise the oxygen concentration in and around the head and neck. This oxygen-enriched atmosphere is an often unsuspected fire risk area during a monitored anesthesia care procedure. The oxygen-enriched atmosphere raises the risk of fire because it lowers the temperature and energy required to ignite a fire. As the oxygen concentration rises above that in ambient air, the fires in the oxygen-

Table. The fire triangle*

Ignition sources
Electrosurgery
Surgical lasers
Electrocautery units
Fiberoptic light sources
Sparks
Argon beam coagulators
Heated probes
Drills and burrs
Defibrillators
Oxidizers
Oxygen
Nitrous oxide
Medically compressed air
Ambient air
Fuels
Tracheal tubes
Breathing circuits
Masks
Laryngeal mask airways
Surgical drapes
Ointments
Operating table mattresses
Sheets and blankets
Caps, gowns, booties, and gloves
Bandages, dressings, and sponges
Alcohol, acetone, and ether used in skin preps, tinctures, and degreasers
Petroleum jelly
Body hair
Intestinal gases
Body tissues
Blood pressure cuffs
Laser fiber sheaths

*** Although each member of the surgical team usually controls 1 item (eg, oxidizers—anesthesia providers; fuels—operating room staff; ignition source—surgeons), everyone must remain vigilant.**

enriched atmosphere spread faster, burn hotter, and are more vigorous and intense than those in room air.

Prevention of fires

Prevention begins in the preoperative period. The OR staff must ensure that electrosurgical equipment undergoes scheduled maintenance. Maintenance of visible labels indicating calibration and assuring that medical maintenance is provided in compliance with local protocols and manufacturer recommendations is essential.

Surgical scrub teams must work closely together and ensure that when they are performing electrosurgery, electrocautery, or laser surgery, the electrosurgical electrodes are placed in a holster or other location off the patient when not in use and lasers are placed in the standby mode. Following the patient prep, staff must allow time for complete drying of any flammable prep solution, remove all dampened prep materials, and prevent pooling of the solution. There may be circumstances during head and neck cases under monitored anesthesia care in which, due to patient health status, large local oxygen concentrations are necessary. Increased attention to the potential for surgical fires is essential during procedures in which these risks are unavoidable.

Surgeons must select the minimum wattage necessary to accomplish the task. The tip of the electrosurgical unit should be kept clean to minimize the likelihood of sparking or burning of tissue debris. During oropharyngeal surgery, soaking the gauze, pledgets, or sponges used with uncuffed ETTs minimizes leakage of oxygen into the oropharynx. In addition, keeping them wet increases their resistance to ignition.[16] Irrigation and observation for blood on the surface of metallic foil–wrapped or special tracheal tubes is important. Blood and tissue residue can make laser-induced combustion more likely.[17] Ensure that when the potential for airway fire exists, syringes of physiologic solution are immediately available to extinguish the fire.

The risk of surgical fires is highest in head and neck surgeries, and in these procedures, the anesthesia provider must share the airway with the surgeon and might be unable to immediately access the airway because of positioning of the patient. Increased vigilance and preventive measures should decrease the likelihood of adverse events from surgical fires in these circumstances.

Anesthesia providers can take a number of precautions to decrease the likelihood of oxidizers contributing to the risk of fire. Use of a pulse oximeter to evaluate arterial oxygenation allows titration of oxygen and, in some procedures, eliminates the need for supplemental oxygen.[18,19] Reducing the fraction of inspired oxygen (Fio_2) to less than 30% has been demonstrated to significantly reduce the risk of ignition or explosion.[20] When an open breathing system is used, scavenging the oxygen and tenting the drapes allows air circulation, which not only prevents the buildup of oxygen under the drapes but also lessens the intensity of a fire in case one gets started.

Establishing a good seal with an ETT or a laryngeal mask airway cuff minimizes oxygen spillage into the operating field. Appropriate sizing of the ETT in pediatric operations also will minimize the leak of oxygen into the surgical field. Whenever possible, laser-resistant ETTs should be used for laser procedures. Remember to follow the manufacturers guidelines for laser wavelength, limits of Fio_2, and laser output. During laser surgery, filling the cuff with saline colored with methylene blue serves 2 purposes. First, it serves as an extinguisher if a laser burns into the cuff, and second, it is a visual warning to the surgeon that the cuff has been damaged.[21] Research also indicates that filling the cuff with saline has a protective effect because penetration of the saline-filled cuff does not occur at the same power densities that penetrate air-filled cuffs.[22] Maximal access to the tube must be maintained to permit immediate response to airway fires. In addition, research indicates that if the patient's condition permits the use of positive end-expiratory pressure (5-10 cm of water) can be beneficial—the tube pressure cools the heated part of the tube and blows out the flame if the tube is ruptured by the laser.[23]

Responses to fire

• *Immediate action.* Rapid response to a surgical fire is essential. Unfortunately, unless we have practiced our response so it can occur without significant conscious thought, our emotional responses often delay essential, timely action. A normal first response is disbelief—this cannot be happening. As a result of our disbelief, we fail to act. Eventually, we begin to consider the possibility that this disastrous event is actually occurring—especially if smoke or flame is detected. Finally, we take action.[24]

A number of actions must occur simultaneously and require the cooperation and action of all surgical staff. The equipment causing the fire must be turned off and instruments removed from the surgical field. Copious irrigation to extinguish the blaze, evacuation of smoke, and removal of any burning materials before significant thermal trauma is produced must be done by the surgical team.

During an airway fire, the anesthesia provider must discontinue all gases and remove the ETT if it is on fire. The anesthesia provider then must ventilate with a mask and bag using air until all possible sources of fire or reignition are eliminated. The extent of tissue damage must be evaluated by direct laryngoscopy and bronchoscopy.

For all surgical fires, the location and extent of injury must be documented. Based on the injury, postoperative endotracheal intubation may be required. High humidity, mechanical ventilation, positive end-expiratory pressure, antibiotics, and/or steroids should be considered as indicated.

The staff must complete a critical incident report and carefully review all contributing factors. Such sentinel events must be reported to the JCAHO, ECRI, and appropriate state organizations to raise awareness and decrease the likelihood of others having to experience these tragedies.

• *Postfire airway evaluation.* Postfire airway evaluation recommendations include immediate direct laryngoscopy and bronchoscopy and repeating these examinations at 1 week after the fire and then monthly for up to 6 months. Aggressive pulmonary toilet minimizes short-term morbidity. This short-term morbidity is secondary to sloughing mucosa and mucosal plugging. Long-term complications are often from granulation tissue and airway obstruction.[25] Information from pulmonary function tests and, in some cases, a computed tomography scan of the neck may help determine the path of granulation and the need for surgical intervention.[26]

• *Fire extinguishers.* Although a hospital has a variety of fire extinguishers, not all are suitable for use in the OR or on a patient. Fire extinguishers are not the first solution to a fire but may be necessary for fires that engulf a patient or extend beyond a patient into the room. Carbon dioxide extinguishers are currently the best extinguishers to use for OR and surgical fires. The ECRI recommends 5-lb carbon dioxide extinguishers mounted inside the entrance to each OR in the facility. Carbon dioxide extinguishers release a fog of cold carbon dioxide gas and snow. It smothers and cools a fire without leaving residue. The cold fog may help minimize thermal injury and is unlikely to injure the patient.[3]

Neither water-based nor dry-powder extinguishers are recommended due to their contamination of the surgical site and difficulty in cleaning after their use. In addition, water-based extinguishers can result in electric shock to the users. Halon has been banned from manufacture because of its effect on atmospheric ozone. Halon extinguishers can be used if available, but halon forms toxic pyrolytic products in very hot fires.

Costs of fire

The costs of fire are significant for the injured patient, the surgical team, and the facility in which the surgical fire occurred. Not only must the patient cope with additional injuries, hospitalization, and lost work, but the surgical team and treatment facility suffer as well. Should the patient or the family decide to litigate, the costs often are borne by surgical team members and the facility. The facility may choose to pay the additional healthcare costs for the patient. The negative publicity may have significant ramifications for the future income of all involved. The loss of equipment and possibly an OR, in addition to personnel time spent reporting, repairing, preparing for court, and appearing in court cost the facility as well. The mental and emotional anguish of the responsible team members may cause them to exit their profession.

Training plans

Videos are helpful tools in the educational and training armamentarium. The ECRI routinely evaluates videos to determine whether they correctly explain what surgical fires are, how to avoid them, and how staff should respond if one occurs. A video used in your facility should meet ECRI criteria and have its endorsement. In 2003, the only videos determined by ECRI to meet the criteria were as follows: (1) Fire Safety in the Perioperative Setting (by the Association of Peri-operative Registered Nurses), (2) Operating Room Fire (by Medfilms), and (3) Fire Safety in the OR: A Triad of Prevention (by Mölnlycke Health Care).[4]

All staff must know the locations of fire alarm pull stations, fire extinguishers, and fire hoses and how to use them. They must recognize oxygen and nitrous oxide valves and know how to turn them off. Following the institution's protocols for notifying facility personnel, announcing the fire, and contacting the emergency and fire departments is essential. Everyone must know where airway devices, breathing equipment, and medication are located to facilitate moving the patient from a fire zone. All personnel also must know exit and evacuation routes. Establish the practice of evaluating evacuation routes. Whenever new equipment is placed in the OR area or when there is construction in or near the OR, evacuation routes must be evaluated and exit plans revised accordingly. There may not be time to reroute if the planned exit path is inaccessible.

Using a variety of educational tools—videos, lectures, articles, discussions, scavenger hunts (for teams to identify all the needed equipment and demonstrate their ability to use it), and hands-on training on the use of extinguishers and hoses by local fire departments—can contribute to raising awareness and decreasing the incidence of surgical or OR fires. The ECRI poster, "Only You Can Prevent Surgical Fires," also is an excellent tool (Figure). Fire and safety training should be included as annual requirements for quality improvement and as a portion of patient safety–focused education.

Preventing surgical fires is a responsibility of every member of the surgical team. We must all be aware of

Figure. Recommendations for the prevention of surgical fires

Only *You* Can Prevent Surgical Fires

Surgical Team Communication Is Essential

The applicability of the following recommendations must be considered individually for the needs of each patient.

At the start of surgery:

- Both O_2 and N_2O support combustion. Be aware of possible enriched O_2 and N_2O atmospheres near the surgical site under the drapes, especially during head and neck surgery.
- Question the need for 100% O_2 for open delivery during head/neck surgery.
- As a general policy, use air or $FiO_2 \leq 30\%$ for open delivery.
- Arrange drapes to minimize O_2 and N_2O buildup underneath.
- Use an incise drape to isolate head and neck incisions from O_2 and alcohol vapors.
- Do not drape the patient until all flammable preps have fully dried.
- Coat facial hair near the surgical site with water-soluble surgical lubricating jelly to make it nonflammable.
- Fiberoptic light sources **can** start fires. Complete all cable connections before activating the source. Place source in STANDBY when disconnecting cables.

During oropharyngeal surgery:

- Scavenge deep within the oropharynx with separate suction.
- Wet gauze or sponges used with uncuffed tracheal tubes to minimize leakage of O_2 into the oropharynx. Keep them wet.
- Moisten sponges, gauze, and pledgets (and their strings) to render them ignition resistant.

When performing electrosurgery, electrocautery, or laser surgery:

- Stop supplemental O_2 (if O_2 concentration is >30%) at least one minute before and during use of the unit, if possible.
- Activate the unit **only** when the active tip is in view (especially if looking through a microscope).
- 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 when not in active use.
- Do not place rubber catheter sleeves over electrosurgical electrodes.

Reference: ECRI. A clinician's guide to surgical fires: how they occur, how to prevent them, how to put them out [guidance article]. *Health Devices* 2003 Jan;32(1):5-24.

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A free copy of the ECRI poster, "Only *You* can Prevent Surgical Fires," is available from http://www.ecri.org/ (in the Patient Safety folder). (Reprinted with permission from ECRI.[3])

hazards, diligently follow safe practices, and have a plan in case a fire occurs. Education is the best prevention for fires in the OR. Take the initiative. Lead your facilities' efforts to improve patient safety and decrease the risks of fire.

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