Fire in the Operating Room During Open Heart Surgery: A Case Report

Michael Moskowitz, CRNA, MS
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A patient had a fire in his chest cavity during dissection of the left internal mammary artery before coronary artery bypass graft. The electrosurgical unit indirectly ignited gauze, resulting in a fire. It was determined that oxygen was being entrained into the surgical field through open pulmonary blebs. This case identifies the need for continued fire training and prevention strategies, persistent vigilance, and quick intervention to prevent injury whenever electrosurgical units are used in an oxygen-enriched environment.

Keywords: Fire, open heart surgery, operating room.

Surgical fires are a rare occurrence, but the risk of a fire always exists in the operating room (OR). Healthcare providers strive to make the OR a safe environment, yet when an ignition source (eg, electrosurgery units), oxidizers (oxygen and nitrous oxide), and fuel (lap pads, drapes) are combined, a fire can result. These 3 elements (ignition source, oxidizers, and fuel)—abundant in any OR—make up the fire triangle, as shown in the Figure. The most frequent sources of ignition include electrosurgery units (68%) and laser equipment (13%).1-4 Patients undergoing surgery usually receive supplemental oxygen. In fact, the Emergency Care Research Institute (ECRI), a nonprofit research organization, found that an oxygen-enriched atmosphere was a contributing factor in 74% of all intraoperative fires.1,3 Various fuel sources are found throughout the OR and include surgical drapes, endotracheal tubes, and alcohol-based skin preparations.3

Although each member of the surgical team (surgeon, anesthesia provider, and nurse/scrub technician) principally regulates 1 side of the triangle (Figure), all team members must understand each component of an OR fire and be vigilantly aware of its devastating potential. Effective fire prevention, detection, and response are possible only if the entire surgical team understands the fire risks, is educated about handling these emergencies, and undergoes regular fire scenario training.1,3

Case Report

A 58-year-old patient, with a weight of 98 kg and height of 183 cm, presented to the hospital for scheduled coronary artery bypass graft (CABG). The patient was initially met in the preoperative holding area, where a chart review and physical examination were completed. The medical history included coronary artery disease, hypertension, and dyslipidemia. His surgical history included bilateral thoracotomies and pleurodesis for treatment of spontaneous pneumothoraces secondary to pulmonary blebs 20 years earlier. Both personal and familial anesthetic histories were without complication. He had a 20-year history of smoking cigarettes but had stopped smoking 14 months before this admission. Current medications included amlodipine, 5 mg; atorvastatin, 80 mg; ramipril, 2.5 mg; metoprolol, 25 mg; nicotine patch, 7-14 mg; and aspirin, 81 mg (last dose 4 days before admission). No additional over-the-counter or herbal medications were disclosed. The patient denied any drug or food allergies.

Preoperative electrocardiogram (ECG) demonstrated normal sinus rhythm at 70/min. Additional baseline vital signs included blood pressure (BP) 118/62 mm Hg and saturation of oxygen in blood (SpO2) of 100% on room air. Chest x-ray showed mild hyperinflation of bilateral apices with a stable, small right pleural effusion. Cardiac catheterization showed total occlusion of the left anterior descending (LAD) coronary artery, obtuse marginal (OM) artery,
and the mid right coronary artery (RCA). Transthoracic echocardiogram demonstrated an ejection fraction of 33% to 40%, with no evidence of valvular disease. Except for elevated cholesterol and triglyceride levels, laboratory values were found to be within normal limits.

On physical examination, vital signs were stable, and the patient was alert and oriented. No neurologic deficits were noted, lungs were clear to auscultation bilaterally, and cardiac rate and rhythm were regular without clicks, murmurs, or rubs. The airway examination revealed that the patient had full extension of his neck, thyromental distance of approximately 7 cm, and a Mallampati grade 1 view. Dentition was intact and nonremovable. The patient's last food or drink was 10 hours before arrival at the OR.

In the OR, standard monitors were applied and an intravenous (IV) line was established. Baseline vital signs were obtained, and oxygen was provided via nasal cannula. Midazolam (2 mg) and cefazolin (2 g) were given intravenously, followed by placement of a radical arterial line. Upon induction of anesthesia, the patient received 3 mg of midazolam, 250 µg of fentanyl, 20 mg of etomidate, and 12 mg of pancuronium intravenously. Direct laryngoscopy was performed, and an 8.0-mm endotracheal tube (ETT) was placedatraumatically. The ETT cuff was inflated and the tube was secured at 23 cm at the lip once bilateral breath sounds and end-tidal carbon dioxide (ETCO2) levels were obtained. Initial peak inspiratory pressure (PIP) was not documented on the anesthesia record but was within normal limits.

Anesthesia was maintained at a fraction of inspired oxygen (FiO2) of 0.5 with oxygen and air, titration of end-tidal sevoflurane (1.9% to 2.1%), in addition to a midazolam, fentanyl, and vecuronium infusions. Tranexamic acid, 1 g, was given intravenously. A 9 F double-lumen central line was placed via the right internal jugular vein using sterile technique, and a pulmonary artery catheter was floated into place and secured at 52 cm. Vital signs at the time, on an FiO2 of 0.5, were as follows: heart rate (HR), 62/min; SpO2, 100%; BP, 108/62 mm Hg; ETCO2, 34 mm Hg; temperature, 36.4°C; pulmonary artery systolic pressure/pulmonary artery diastolic pressure (PAS/PAD), 33/13 mm Hg; central venous pressure (CVP), 9 mm Hg; and cardiac output (CO), 4.8 mL/min.

Sternal incision was made at 9:03 AM, and dissection of the left internal mammary artery with bipolar cautery began soon thereafter. Ventilation was maintained with tidal volumes (VT) of 650 to 750 mL per breath, frequency of 10 breaths per minute, FiO2 of 0.5, and SpO2 of 100%.

At 10:05 AM, VT suddenly decreased to 200 to 300 mL per breath. The endotracheal tube's position and balloon were checked, the anesthesia machine and circuit were assessed for leaks, and all connections were tightened and the anesthesia circuit changed. There was no increase in VT, and both oxygen and air flow were increased to 8 L/min to compensate for decreased VT, while the FiO2 remained at 0.5.

At 10:10 AM, the surgeon notified the anesthesia team that the patient's pulmonary blebs were leaking, attributing to the loss of VT. In an attempt to decrease the VT loss, the surgeon placed moist gauze over the leaking blebs. Approximately 3 minutes later a fire ignited in the surgical field. The gauze lining the patient's chest cavity erupted into flames. The surgeon pulled the burning gauze from the patient's chest, the FiO2 was decreased to 0.21, and the scrub nurse doused the burning gauze with sterile water. Within seconds the fire was extinguished. Inspection of the chest cavity showed no signs of charring or tissue damage. The endotracheal tube and patient's respiratory function were assessed for possible inhalational injury, and it was determined that no injury had occurred.

Vital signs following the fire on an FiO2 of 0.21 were as follows: HR, 78/min; SpO2, 100%; BP, 130/62; ETCO2, 34 mm Hg; temperature, 36.2°C; PAS/PAD, 27/13 mm Hg; CVP, 12 mm Hg; and CO, 6.9 mL/min.

In an effort to reduce the risk of another fire, the bipolar electrocautery unit milliamperes (mA) were decreased; FiO2 was maintained at 0.30, with 1 L/min of oxygen and 8 L/min of air to compensate for the leak. Arterial blood gas (ABG) analysis before the fire on a FiO2 of 0.5 showed an oxygen saturation of 99% with a partial pressure of oxygen in arterial blood (PaO2) of 173 mm Hg. After the fire was extinguished, an ABG analysis was obtained on room air (FiO2 of 0.21), with oxygen saturation decreasing to 95% and a PaO2 of 82 mm Hg.

Measured exhaled VT remained low until cardiopulmonary bypass was initiated. Once the patient was on bypass, the surgeon used a synthetic hydrogel surgical sealant to correct the leaking pulmonary blebs. The remainder of surgery was uneventful, with successful completion of a 2-vessel CABG. While the patient was coming off bypass, ventilation was maintained with VT of 500 to 600 mL per breath, without a leak. The patient was transported to the cardiothoracic intensive care unit, where he remained intubated, arousable to commands, and spontaneously ventilating with VT greater than 500 mL per breath.

The patient experienced a normal postoperative course without complications, and he was discharged home in the care of family on postoperative day 5.

Discussion
In June 2003, the Joint Commission on Accreditation of Healthcare Organizations, now known as The Joint Commission, issued a Sentinel Event Alert bulletin in an effort to raise awareness about preventing surgical fires. According to the bulletin, “there are approximately 100 surgical fires each year, resulting in up to 20 serious injuries and one or two patient deaths annually.”

Well-established principles of chemistry require 3 ingredients for the rapid exothermic reaction known as fire to occur: fuel, oxidizer, and an ignition source. During
this surgical procedure, all of the ingredients that support combustion were present. These 3 elements, which constitute the fire triangle, are prevalent in OR settings and provide many opportunities for unexpected fires to occur.1 Understanding the fire triangle and how to properly manage its components can greatly reduce the risk of fire. The anesthesia provider controls the flow of oxidizers, including oxygen, nitrous oxide, and medical air. Scrub nurses and technicians supply the fuel, such as sheets, gowns, towels, drapes, dressings, and sponges. The surgeon most often provides the ignition through the use of electrocautery equipment, surgical lasers, electrocautery equipment, fiberoptic light sources, and defibrillators.1

Ignition sources provide the heat necessary to start a fire should that heat source come in contact with an oxidizer, a fuel source, or both. With the tip of an electrocautery unit reaching nearly 816°C, electrocautery is the most common ignition source in surgical fires.3 To reduce electrocautery fires, electrocautery units should be placed in a holster when not in active use, and bipolar units should be used whenever possible to reduce sparking and arcing.

The second most common source of ignition is lasers. Frequently used during urologic cases for the treatment of kidney stones, lasers have been cited as a potential source of ignition when misfired or misdirected.1,3 When not in use, lasers should be placed in the standby mode.

Fiberoptic light sources provide a high-intensity, concentrated beam of light that has the potential to burn or ignite flammable materials. Fiberoptic cables should never be placed on flammable materials and should always be turned off when not in use.1,3

Fuel sources are abundant in any environment and especially in the OR. Sources of fuel can be found on or in a person (hair, tissue, gastrointestinal tract gases), in prepping agents (alcohol, degreasers, tinctures), dressings (gauze, sponges, petroleum-based ointments), linens (surgical drapes, gowns, equipment covers), and in the equipment used (endotracheal tubes, masks, gloves, blood pressure cuffs). Although most of these fuels will ignite and burn in air, it is important to understand that all will burn in an oxygen-enriched environment.1,3 Some surgical materials are produced with fire retardants, but such retardants cannot be relied on to prevent fires.1,3 When patients are prepped with alcohol-based products, a sufficient amount of time should be allowed for the product to completely dry, as flammable vapors may become trapped under surgical drapes. As a rule, most materials in the OR are flammable, and precautions to prevent fires should be the priority of the entire team.1,3,4

Oxidizers are gases, such as oxygen and nitrous oxide, that can support combustion.3 During surgical procedures, anesthesia often requires delivering oxygen-enriched mixtures above the 21% oxygen of room air to ensure proper oxygenation of the patient. Whenever and wherever the oxygen concentration is above 21%, an oxygen-enriched atmosphere exists. With increased oxygen, a fire is easier to ignite, will burn faster and hotter, and will be more difficult to extinguish.7 Additionally, oxygen for a fire can also be supplied from the thermal decomposition of nitrous oxide, and any mixture of oxygen and nitrous oxide should be considered an oxygen-enriched atmosphere.8 Many materials that would not burn or sustain a flame in ambient air will do so in an oxygen-enriched atmosphere.3

To minimize the risk of fires in the OR, providers of medical and anesthetic gases should thoroughly understand the potential for combustion. Providers should always question the need for high oxygen concentrations and, if possible, adjust the concentration to the minimum level required by the patient.3 Likewise, providers must be aware of possible oxygen and oxygen/nitrous oxide-enriched environments near surgical sites and under the drapes. Finally, when possible, providers should use properly applied incise drapes to isolate the head and neck from the surgical site. When used correctly, these drapes ensure that there are no gas communication channels from the under-drape space to the surgical site.1

Conclusion

After further review of this case, it was determined that the risk of fire could have been reduced and that the precipitating problem was ineffective communication between surgical team members. In fact, communication failures have been uncovered at the root of more than 60% of sentinel events reported to the Joint Commission on Accreditation of Healthcare Organizations (now known as The Joint Commission).9 In this case, a systematic approach was used to identify the source of the air leak, including assessment of the patient, endotracheal tube, anesthesia machine, and circuit. However, although these checks and balances were performed, there was a delay in communicating to the surgeon that a leak was present. The source of the leak may have been identified sooner, and before a fire could ignite, if the surgeon and anesthesia team had communicated effectively when tidal volumes first decreased.

To foster better communication, the OR team should complete a time-out and debriefing before the start of any operative procedure. This should include the introduction of every member in the OR and their roles, stating the planned procedure, a review of the patient’s medical history and allergies, antibiotics required, and a discussion related to any concerns about the patient or procedure. Additionally, any intraoperative change in patient condition should be communicated clearly and promptly to all team members in the OR.

Specific to this case, knowledge of the patient’s prior medical and surgical history by both the anesthesia providers and surgeon should have aroused suspicion for

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potential bleb rupture, which could have been discussed during a preoperative debriefing. During positive-pressure ventilation, alveolar pressure rises more than interstitial pressures, allowing pressure gradients to develop between alveoli and perivascular connective tissues, potentially causing rupture of weakened blebs. Although it is unknown whether rupture could have been prevented, measures to decrease mean airway pressure should have been implemented ahead of time. With very little documentation available to suggest the appropriate mode of ventilation in a patient with known pulmonary blebs, pressure control ventilation with low PIP may have been a better choice to use for this patient, instead of volume control ventilation.

Like most reports of surgical fire, it is likely that an oxygen-rich environment contributed to the surgical fire in this case, because the delivery of a large concentration of oxygen (0.5 FiO₂) was being entrained into the surgical field through leaking pulmonary blebs. Increasing gas flows to compensate for decreased tidal volumes without adjusting the fractional inspired oxygen content only provided for a greater oxygen-enriched environment. Moreover, because oxygen is heavier than air, it collects in low-lying areas, including the open chest cavity and in drape folds. Whenever possible, the oxygen concentration should be lowered and because the patient was oxygenating adequately, the FiO₂ should have been decreased.

Although the surgeon stated that they initially applied saline-soaked gauze in and around the patient’s chest cavity, it had dried enough to become a fuel source. Ensuring that gauze and towels in and around the incision are adequately moist can decrease the chance of ignition, especially when working around the face, neck, and open chest cavity. In the event that oxygen or another combustible gas is leaking into the operative field, placing moist gauze over the leak is not a recommended technique to prevent further leakage. This may actually potentiate the risk of fire as the gauze dries and becomes saturated with the gas. Instead, surgical technique to seal a leak should be performed as soon as it is identified.

Operating room fires remain a constant danger to both patients and medical providers. It only takes an instant for a fire to occur, as it did in this case. Every member of the perioperative team must be educated with regard to handling fire emergencies and extinguishing fires quickly. The rapid response by all individuals in the OR during this case prevented the spread of the fire and allowed it to be extinguished without injury to the patient or any medical providers. The potential risk for a fire to occur in the OR, especially in cases involving the head, neck and open chest cavity, needs to be appreciated and understood. Methods to reduce fire risk should be in place, and fire drills and mock scenarios need to be practiced regularly. When a fire occurs, quick action during the first few seconds can make the difference between a survivable event and a poor outcome that may include patient injury or death.

REFERENCES

AUTHOR
Michael Moskowitz, CRNA, MS, is a staff nurse anesthetist at Mount Sinai Medical Center, New York, New York. At the time this article was written, he was a senior student nurse anesthetist at Columbia University, New York, New York. Email: michael.moskowitz@mountsinai.org.

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