Surgical Smoke: Hazards and Prevention

David Blevins, CST, CSFA

Surgical smoke is one of the most common hazards encountered in the operating room. Unfortunately, it continues to be one of the most overlooked dangers by many surgeons and OR staff. It is critical for the surgical technologist to be aware of the dangers of surgical smoke and diligent in their efforts to help minimize the risks.

WHAT IS IT?

Surgical smoke or surgical plume is a gaseous byproduct generated during surgical procedures. It is most commonly associated with the use of electrocautery or lasers, although it can be produced by any means in which tissues are rapidly heated and cells vaporized. Surgical smoke is composed of approximately 95% water and 5% cellular debris and other chemicals.[1] It has been shown to pose a risk for physical, chemical and biological hazards for those who inhale it.

The terms "smoke" and "plume" often are used synonymously, but technically there is a difference – the size of their airborne particles. Plume contains larger particles, which are thought to be more dangerous from a biohazard standpoint, as they are capable of adhering to the lining of the upper respiratory tract. Smoke contains smaller particles, which can pass easily into the deepest regions of the lungs. These are a

LEARNING OBJECTIVES

- Define surgical smoke and surgical plume
- Read about how the OR personnel may be affected by surgical smoke
- Recall the risks and hazards surgical smoke can cause to patients
- List the methods used to reduce the risk of exposure
- Identify the barriers to compliance with smoke evacuation guidelines

concern due to the harmful chemicals they may contain.[2] Particle size in surgical smoke is dependent upon the method of generation (see Table 1).

METHODS OF GENERATION

As much as 80% of smoke encountered in the operating room is produced by the use of traditional electrocautery devices.[3] As previously mentioned, this type of smoke often is considered to be less of a biological hazard than smoke generated by other means because the airborne particles are smaller. The average particle size found in electrocautery smoke ranges from 0.007-0.42μm (micrometers).[4] The small size, however, means they are capable of traveling farther in the air and reaching more OR staff. Additionally, the lower health risk may be offset by its sheer prevalence. Electrocautery is used in approximately 80% of modern surgical procedures.[5]

Another common source of surgical plume is lasers. Lasers produce extreme heat (100 to 1000 degrees Celsius), which boils and explodes cells, releasing steam and cellular contents.[6] Most studies on laser plume have involved the CO2 or Nd:YAG laser. Laser plume is associated with a higher risk of disease transmission due to larger particulate matter, ranging in size from 0.1-0.8μm.[4]

The growing popularity of ultrasonic scalpel devices in the last decade has added to the prevalence of surgical smoke. Ultrasonic scalpels have become a popular alternative to traditional electrocautery for dissection because they produce less thermal damage to surrounding tissue. They utilize high frequency vibration – as much as 55,000 times per second – to cut and coagulate tissue. This low temperature vaporization comes at a price as the vapors generated are more likely to carry infectious particles than vapor generated by high temperature.[7]

Finally, a very common but often ignored source of dangerous smoke and aerosol in the operating room are power instruments used in orthopedic surgery. The rapid movement of bone saws, drills, etc, generates heat and disrupts cells, sending potentially hazardous material into the air.

RISKS AND HAZARDS TO OR PERSONNEL

The hazards associated with surgical smoke can range from mild irritation to life threatening illnesses, affecting both scrubbed and non-scrubbed staff. The most common and least threatening symptoms associated with exposure include eye irritation, headaches, light-headedness and respiratory irritation.

Table 1. Sizes of Particles produced by various surgical devices[4]

Electrocautery	0.007-0.42μm
Laser	0.1-0.8μm
Ultrasonic scalpel	0.35-6.5μm

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Surgical smoke contains a number of chemicals known to be respiratory irritants and carcinogens, such as benzene, formaldehyde, cyanide and ethanol, among others (see Table 3). Inhalation of these chemicals can lead to acute and chronic conditions including emphysema, asthma and bronchitis.[8] A study among perioperative nurses showed that they have an increased prevalence of respiratory illnesses (sometimes twofold) compared to the general population (see Table 2).[9] Studies have also shown that the smoke produced by the vaporization of 1g of tissue is equivalent to smoking three to six unfiltered cigarettes.[1]

Multiple studies have shown surgical smoke to contain viable bacteria and viruses. One study cultured laser plume in 13 surgical procedures – of these, five specimens grew *Staphylococcus.* Among those five specimens, two of them also grew *Corynebacterium* (associated with diphtheria) and *Neisseria.*[4]

One of the best known risks to OR staff is the potential transmission of human papillomavirus (HPV). This comes from a well-documented case of a surgeon who developed laryngeal papillomatosis after treating a patient for anogenital papilloma with a Nd:YAG laser. Further study of the surgeon revealed HPV types 6 and 11 in his larynx, the same types found in anogential papilloma. This virus could have only been transmitted through inhalation. Viable human immunodeficiency virus (HIV) also has been found

in aerosols generated by power oscillating saws, although there have been no proven cases of transmission and further study is needed.[4]

RISKS AND HAZARDS TO PATIENTS

While most of the concern regarding hazards of surgical smoke leans toward OR personnel, patients are also at risk, particularly in laparoscopic procedures. One of those risks is carbon monoxide (CO) toxicity. CO contained in surgical smoke is absorbed into the patient's body through the peritoneum. Overexposure to CO has been shown to cause headaches, fatigue, nausea, vomiting and cardiac dysrhythmias. Increased peritoneal CO increases carboxyhemoglobin levels in the blood. Carboxyhemoglobin is produced when CO binds to hemoglobin. Carbon monoxide has an affinity for hemoglobin more than 200 times greater than oxygen.10 This reduces the oxygen carrying capacity of red blood cells. Pulse oximeters interpret carboxyhemoglobin as oxyhemoglobin, giving an inaccurate SpO2 reading to the anesthesia provider and potentially resulting in unrecognized hypoxia in the surgical patient.[11]

Surgical smoke is thought to be responsible for port site metastasis following laparoscopic tumor resection. Malignant cells have been identified in trocar sites other than the ones used to deliver the cancerous specimen, suggesting

Table 2. Prevalence of Respiratory

Respiratory Illness	Prevalence in study of perioperative nurses	Prevalence in study of general population
Allergies	24.23%	18.38%
Sinus Infections	22.93%	10.33%
Asthma	10.87%	6.4%
Bronchitis	9.04%	4.45%

Table 3. Common Chemicals in Surgical Smoke[7]
Acetonitrile
Acetylene
Acroloin
Acrylonitrile
Alkyl benzene Benzaldehyde Benzene
Benzonitrile Butadiene
Butene 3-Butenenitrile
Carbon monoxide Creosol
1-Decene (hydrocarbon)
2,3-Dihydro indene (hydrocarbon)
Ethane
Ethene
Ethylene
Ethyl benzene
Ethynyl benzene
Formaldehyde Furfural (aldehyde) Hexadecanoic acid
Hydrogen cyanide Indole (amine) Isobutene Methane 3-Methyl butenal (aldehyde) 6-Methyl indole (amine) 4-Methyl phenol 2-Methyl propanol (aldehyde)
Methyl pyrazine Phenol
Propene 2-Propylene nitrile Pyridine
Pyrrole (amine) Styrene
Toluene (hydrocarbon) 1-Undecene (hydrocarbon) Xylene

that viable cancer cells spread to that location through surgical smoke. This phenomenon has become known as "the chimney effect." Tumor cells carried by the carbon dioxide used for pneumoperitoneum leaks around the trocar and becomes trapped in the wound surface, leading to malignant seeding at the trocar site.[12]

Finally, in laparoscopic cases, surgical smoke can impair the vision of the surgeon and assistants, requiring periodic ventilation of the abdomen or requiring the surgeon to repeatedly remove the scope to clean obstructing debris. Successful laparoscopy requires consistently clear visualization of the surgical field. If visualization if not optimal in an emergent situation, such as hemorrhage, the results could be fatal.[13]

REDUCING THE RISK

The Occupational Safety and Health Administration (OSHA) estimates that as many as 500,000 healthcare workers are exposed to surgical smoke each year, however, there are no official mandates related to the prevention of surgical smoke production or inhalation.[7] Without regulations in place, many facilities have been slow to adopt preventive measures, leaving surgeons and operating room personnel to protect themselves from harm. The following are common methods of defense against surgical smoke:

Avoiding unnecessary use of electrosurgery

The invention of electrosurgery is one of the greatest advancements in the history of the surgical profession, so it's unreasonable to think that its use will decline in the near future. Nevertheless, surgeons still can be mindful of the amount of smoke they generate and take small steps to reduce it, such as not using the ESU pencil for skin incisions and opting for dissection with standard instrumentation when possible.

Surgical masks

Traditional surgical masks provide little barrier to the harmful particles in surgical smoke. Most surgical masks only filter particles larger than 5µm. As many as 77% of particles in smoke are 1.1µm or smaller. Laser masks can provide better protection by filtering particles as small as 0.1µm.[6] The primary disadvantage of surgical masks, including laser masks, is that they cannot provide a tight enough fit to prevent inhalation of surgical smoke from the bottom or sides of the mask. This is especially true with ear-loop style masks, which lose their elasticity during the course of a procedure. Respirator masks (N95 and higher) are likely to provide the best protection against surgical smoke.[4]

Wall suction

A common and quick method of dealing with surgical smoke is to place a standard surgical suction tip, connected to wall suction, at the surgical site. While this method may be somewhat effective for removing small amounts of smoke, wall suction is not strong enough to be effective when large amounts of smoke are involved. Additionally, for this method to be effective, an "in-line" smoke filter should be used between the suction tubing and canister.[14] Without the use of inline filters, smoke will easily escape from suction canisters and permeate back into the room air.

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Smoke evacuation systems

The National Institute for Occupational Safety and Health, or NIOSH, recommends the use of local exhaust ventilation (LEV) through a high velocity smoke evacuation system. Surgical smoke evacuators are multistage systems consisting of a capture nozzle, a pre-filter to capture larger debris and aerosols (as small as 5µm), a HEPA or ULPA (ultra-low particulate air) filter, which can filter particles as small as 0.01µm, and a carbon filter to neutralize odors.[3] Capture nozzles will vary in size and style. Traditional wand-style devices should be placed no more than two inches from the smoke source. Smoke evacuation adapters are designed to attach to standard ESU pencils and allow the nozzle inlet to be much closer to the smoke source without obstructing the surgeon's view.

Recommended smoke evacuation systems pull at a rate of 100-150 feet per second, compared with around 5 feet per second with wall suction.[15] Use of smoke evacuator systems is also advocated by AST, the American National Standards Institute and AORN.

BARRIERS TO COMPLIANCE

As previously stated, surgical smoke is one of the most overlooked hazards in the operating room, despite the abundant studies confirming its danger and the recommendations of multiple authoritative and national organizations. A 2011 NIOSH study of healthcare workers showed that compliance with smoke evacuation guidelines is alarmingly low. The study, with more than 4,700 respondents found that only 47% reported that smoke evacuation is "always" used with laser surgery and only 14% reported that it always was used with electrosurgery. This same study reported that smoke evacuation is "sometimes" used 22% of the time with lasers and 26% with electrosurgery. Smoke evacuation was "never" used for 21% of laser surgery cases and 36% of electrosurgical cases.[16]

So why do so many surgeons, staff and facilities not take the appropriate action to prevent against the hazards of surgical smoke? A study found the top four barriers to compliance with smoke evacuation guidelines were: the physician said it was unnecessary, smoke evacuators were not available, smoke evacuators are thought to be too noisy and staff complacency.[17]

Operating room personnel need to be proactive in their efforts to minimize the risks associated with surgical smoke. Even though the most common hazards seem to be short term and minor, healthcare workers always should be mindful of the potential adverse effects and damage that could be caused over the course of an entire career.

The previously quoted NIOSH study showed that more than 40% of OR workers reported they have had no formal training on the hazards of surgical smoke.[14] Educating OR personnel will require a team effort including management and those on the front lines. Administrators should provide in-services or surgical smoke education for all surgeons and employees. Surgeons should take efforts to minimize smoke production and properly evacuate smoke that is produced. Surgical technologists, surgical assistants and nurses will need to speak up when best practices are not being followed. By working together, all members of the surgical team will help clear the air and make the OR a healthier environment.

ABOUT THE AUTHOR

David Blevins, CST, CSFA, from Cincinnati, has worked in the OR since 2005. He is currently the clinical coordinator and an instructor for the surgical technology program at the University of Cincinnati, Clermont College. He earned a bachelor's of health science from Northern Kentucky University and an associates of applied science in surgical technology from the University of Cincinnati.

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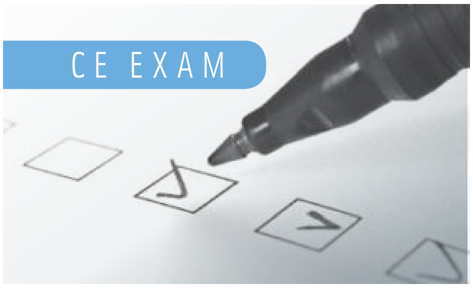

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1. Electrocautery is used in approximately ___ of modern surgical procedures.
- **a.** 50%
- **b.** 60%
- **c.** 70%
- **d.** 80%

2. Surgical smoke is mainly comprised of:
- **a.** Cyanide
- **b.** Cellular debris
- **c.** Water
- **d.** Benzene

3. Studies performed about surgical smoke have shown that the smoke produced by the vaporization of 1g of tissue is equivalent to smoking ___ unfiltered cigarettes.
- **a.** 1-2
- **b.** 3-6
- **c.** 2-5
- **d.** 6-8

4. One of the highest risks to patients is ________.
- **a.** Ingesting cyanide
- **b.** Contracting a virus
- **c.** Carbon monoxide toxicity
- **d.** Hypoxia

5. The "chimney effect" is when ________ are spread to the wound site by surgical smoke.
- **a.** Cancer cells
- **b.** Hemoglobin
- **c.** Carboxyheoglobin
- **d.** HPV

6. The Occupational Safety and Health Administration, or OSHA, estimates that as many as ______ healthcare workers are exposed to surgical smoke each year.
- **a.** 100,000
- **b.** 250,000
- **c.** 500,000
- **d.** 1 million

7. Which of the following are common methods of defense against surgical smoke:
- **a.** Surgical masks
- **b.** Wall suction
- **c.** Smoke evacuation systems
- **d.** All of the above

8. In a 2011 NIOSH study of healthcare workers, __ and __ reported that smoke evacuation was never used for laser and electrosurgical cases, respectfully.
- **a.** 22% and 26%
- **b.** 47% and 14%
- **c.** 21% and 36%
- **d.** 25% and 37%

9. When using a smoke evacuation system, wand-style devices should be placed no more than ____ from the smoke source.
- **a.** 2 inches
- **b.** 3 inches
- **c.** 4 inches
- **d.** 5 inches

10. For a wall suction to be effective, a(n) ___________ will need to be used between the suction tubing and canister.
- **a.** Suction tip
- **b.** ESU pencil
- **c.** Inline smoke filter
- **d.** Cap nozzle

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