The Hazards of Surgical Smoke

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Surgical smoke is part of the patient care environment wherever surgical or invasive procedures are performed. It is called by a variety of names, including plume, smoke plume, diathermy plume, cautery smoke, aerosols, bioaerosols, vapors, and air contaminants. Surgical smoke results from the interaction of tissue and mechanical tools or heat-producing equipment, such as those that are used for dissection and hemostasis. Surgical smoke can be seen and smelled. Both the visible and the odorous components of surgical smoke are the gaseous by-products of the disruption and vaporization of tissue protein and fat.[1]

Surgical smoke has been described as part of the "chemical soup" that is present during the care of perioperative patients.[2] The components of surgical smoke have been described as being, at the very least, a nuisance and, at worst, carcinogenic. Since 1975 when Mihashi et al[3] expressed concern that smoke particles were small enough to be inhaled, researchers and practitioners have continued to evaluate surgical smoke and document their findings.

One point that has not been made is that surgical smoke is safe. Indeed, some staunchly believe there is no such thing as "safe smoke." Thus, it seems prudent to err on the side of safety and protect patients and health care workers from any potential dangers from surgical smoke. Erin Andersen, MS, RN, OHNP, characterized the issue well in 2005 by raising a provocative question:

> *In hindsight, will health care professionals be embarrassed about their cavalier attitudes toward surgical smoke as they once were with cigarette smoke?*[4(p104)]

Efforts to Raise Awareness

AORN hosted its first multidisciplinary roundtable discussion on surgical smoke in January 1996. The outcomes of the discussion were chronicled in Giordano's 1996 article, "Don't be a victim of surgical smoke."[5] The event brought together experts from the Occupational Safety and Heath Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and the

ABSTRACT

SURGICAL SMOKE is a part of the environment during operative and invasive procedures. As lasers and electrosurgery have become commonplace, perioperative practitioners are at increased risk for health concerns associated with exposure to surgical smoke.

SINCE THE MID 1970s, the body of evidence documenting the hazardous components of surgical smoke has continued to grow. Despite the evidence and recommendations of a variety of organizations, there are no uniform requirements mandating surgical smoke evacuation.

THIS ARTICLE REVIEWS current research to identify the potential health hazards as well as the current recommendations related to the filtration and evacuation of surgical smoke. *AORN J* 87 (April 2008) 721-734. © AORN, Inc, 2008.

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The most common heat-producing device is the electrosurgical unit, which uses radio-frequency current to cut (ie, vaporize) and coagulate (ie, fulgurate) tissue.

ECRI (eg, formerly known as the Emergency Care Research Institute), as well as researchers, surgeons, RNs, and health care product manufacturers. As a result of the conference, NIOSH sent out a *Hazard Alert* to all hospitals in the United States in September 1996 recommending that smoke from lasers and electrosurgical units (ESUs) be filtered and evacuated.[6]

AORN continued efforts to raise awareness about the hazards of surgical smoke by hosting a second conference on smoke in February 1997. The second meeting brought together experts from the same groups but added representatives from the American Society of Anesthesiologists, the American College of Surgeons, the American Nurses Association (ANA), and the Joint Commission on the Accreditation of Healthcare Organizations, now known as the Joint Commission. One goal of the awareness effort was to include as many organizations as possible to increase consensus about the best methods to effect change in the regulation of surgical smoke.[7]

The most important outcome of the second smoke conference was the development of a guidance document from OSHA that was intended to support evacuation of surgical smoke. The detailed, 20-page document was sent out to reviewers in 1998 in anticipation of publication and was similar in scope to the 1996 NIOSH alert.[8] By the year 2000, the guidance document still had not been published, and in July 2000, OSHA stated that the delay was caused by a need for more evidence.[9]

Despite OSHA's failure to publish the guidelines, the concern and controversy surrounding the issue of surgical smoke and air quality in the OR continue. Efforts to improve the quality of work-life circumstances have spread to professional organizations in other countries because the state of caregivers' health is of increasing concern. In 2003, AORN published the "Position statement on workplace safety," which stated,

> *The workplace safety culture is of increasing importance as workloads increase, due to the effects of the nursing shortage, increased patient acuity, and emphasis on higher productivity. . . . The multiple occupational hazards that create a risk of personal injury that perioperative nurses face in the workplace are both physical and psychosocial.*[10(p169)]

The position statement lists the hazards faced by perioperative professionals, including smoke plume.[11]

Smoke Production in the OR

A primary mechanism to achieve a desired effect on the tissue (eg, hemostasis, tissue dissection) during surgical procedures is the use of heat-producing devices. These include ESUs; lasers; ultrasonic devices; and high-speed drills, burrs, and saws.

ESUs. The most common heat-producing device used is the ESU. Electrosurgery uses radio-frequency current (ie, high-frequency electrical current). The two basic waveforms are cut (ie, vaporization) and coagulation (ie, fulguration). The cut waveform is a continuous (ie, undampened), low-voltage wave pattern. The continuous current flow heats cell contents to the boiling point of 100° C (212° F), thereby exploding the cell wall.[12] Vaporization releases the cellular fluid as steam, and simultaneously spews the cell contents into the air, forming surgical smoke.

The coagulation waveform is an interrupted (ie, dampened), high-voltage wave pattern. The interruption in the wave pattern is a rest period in the delivery of the electrical current, which causes a more gradual rise in the temperature of the cellular fluid. Above 90° C (194° F), cellular liquid evaporates and proteins are denatured, losing structural integrity. When the

temperature reaches 200° C (392° F), the tissue is carbonized. The depth of necrosis in the tissue is more superficial, unless the active electrode is held in contact with the tissue, which is called desiccation. This method of delivering electrosurgical current will result in greater thermal tissue effect.[13] Desiccation using the coagulation current is preferred by many practitioners, thus carbonized tissue contributes to the cellular debris released into the air.

LASERS. Lasers are the second most common heat-producing device used by surgeons. The term *laser* is an acronym that describes a process in which light energy is produced—light amplification by stimulated emission of radiation. This energy is a concentrated beam of light. It is distinguished from an ordinary light beam because it is monochromatic, collimated, and coherent. Monochromatic light is composed of photons of the same wavelength or color. Collimated laser beams are parallel waves that can be focused through a lens. Coherent waves are orderly and travel in the same direction, providing power to the laser beam. Thermal effects vary with the wavelength; beam fluence (ie, energy density); and tissue color, consistency, and water content. This allows for the provision of selective and specific tissue effects among the various types of lasers.[14]

Surrounding tissue also is heated because it borders the impact site. The degree of adjacent tissue damage depends on the duration of laser beam exposure. Lasers produce high heat (ie, 100° C [212° F] to 1,000° C [1,832° F]), which boils and explodes the cells. This cellular vaporization releases steam and cell contents.[15] The characteristics of the cellular matter are determined by the type of laser being used and the type of tissue being treated.

Lasers and ESUs both work by using high thermal energy, and both release cell contents. When the particulate matter of both laser and electrosurgical smoke are compared, they appear to be very similar.[16] Because of the similarities, facility policies on smoke evacuation should be the same for ESUs as they are for lasers.

ULTRASONIC DEVICES. Ultrasonic devices have gained popularity as dissection and hemostasis tools. Ultrasonic dissection removes tissue by rapid mechanical action. It does not produce sound waves; it is called ultrasonic because vibrations that occur are above the range of human hearing.

The depth of tissue necrosis during coagulation is more superficial than during cutting, unless the active electrode is held in contact with the tissue, which is called desiccation. This method of delivering electrosurgical current results in greater thermal tissue effect.

There are two types of ultrasonic devices: aspirators and scalpels.

- Ultrasonic aspirators have hollow tips. Only tissue that comes into direct contact with the circumferential edge or core of the tip is affected. Minimal thermal damage occurs because the heat generated by the tip is conducted away via irrigation fluid. The tip irrigation produces a fine mist, but the surgical field is cleared continuously by the suction at the tip.
- Ultrasonic scalpels have solid tips or blades. When the tips vibrate, thermal heat is produced by the edge of the blade. This technology allows surgeons to coagulate and divide tissue. The tip vibrates at a frequency of 55,000 times per second, stimulating collagen molecules to denature and form a coagulum.[17] The motion of the tip produces a vapor that, because of lower tip temperatures, could carry infectious aerosols.[18]

HIGH-SPEED ELECTRICAL DEVICES. Often overlooked sources of air contamination in the OR are bone saws, drills, and other high-speed electrical devices used to dissect and resect tissue. These instruments produce heat by rapidly rotating or sawing, thereby disrupting tissue. Because the

saw blades, drills, and burrs get hot, the scrub person often drips irrigation fluid over them to reduce the heat buildup. The mechanical motion of the saw, drill, or burr, combined with irrigation, sends a mist of aerosols into the surgical field. Research has demonstrated that blood-containing aerosols have the potential to invade the breathing zones of scrubbed surgical team members during power tool use.[19,20] This raises the issue of whether aerosols created by power tools may contain viable bloodborne pathogens.[21]

Components of Surgical Smoke

Surgical smoke is made up of 95% water or steam and 5% cellular debris in the form of particulate material. The particulate matter is composed of chemicals, blood and tissue particles, viruses, and bacteria.[22]

Particle size. Each type of heat-producing device produces a different size particle in its surgical smoke or plume (Table 1). The smaller the particle size, the further it can travel. This can affect nonscrubbed members of the surgical team (eg, circulating nurse, anesthesia care provider) during a procedure as well as team members who are scrubbed.[23]

Determining aerosolized particle size is important. Particles that remain airborne are smaller than 100 micrometers in diameter. Particles that are 5 micrometers or larger are deposited on the walls of the nose, pharynx, trachea, and bronchus. Particles that are smaller than 2 micrometers in size are deposited in the bronchioles and alveoli, which is the gas-exchange region of the lungs.[24] Viruses are the smallest in size, ranging from about 0.01 to 0.3 micrometers.[25] By comparison, the thickness of an average human hair is about 200 micrometers.

Taravella and colleagues[24] examined whether respirable-size particles were present during laser use. Particles collected were measured with an electron microscope and had a mean diameter of 0.22 micrometers to 0.056 micrometers. The researchers concluded that the particles were in the inspirable range, but the study did not determine the health hazards of breathing the particles.

Chemical composition. The chemical composition of surgical smoke has been well documented. Barrett and Garber[18] identified a long list of chemicals present in surgical smoke (Table 2). Two of the chemicals of concern were acrylonitrile and hydrogen cyanide. Acrylonitrile is a volatile, colorless chemical that can be absorbed through the skin and lungs. Acrylonitrile liberates hydrogen cyanide. Hydrogen cyanide is toxic and colorless and can also be absorbed into the lungs, through the skin, and via the gastrointestinal tract.

Table 1
Particle Size for Each Type of Heat-Producing Device

Device	Mean aerodynamic particle size
Electrosurgical unit	0.07 micrometers
Laser	0.31 micrometers
Ultrasonic scalpel	0.35 to 6.5 micrometers

Table 2
Chemical Contents of Surgical Smoke[1]

Acetonitrile	Furfural
Acetylene	Hexadecanoic acid
Acroloin	Hydrogen cyanide
Acrylonitrile	Indole
Alkyl benzene	Methane
Benzaldehyde	3-Methyl butenal
Benzene	6-Methyl indole
Benzonitrile	4-Methyl phenol
Butadiene	2-Methyl propanol
Butene	Methyl pyrazine
3-Butenenitrile	Phenol
Carbon monoxide	Propene
Creosol	2-Propylene nitrile
1-Decene	Pyridine
2,3-Dihydro indene	Pyrrole
Ethane	Styrene
Ethyl benzene	Toluene
Ethylene	1-Undecene
Formaldehyde	Xylene

1. Barrett WL, Garber SM. Surgical smoke—a review of the literature. Bus Brief: Glob Surg. *2004;1-7.*

Benzene is another of the chemicals identified in surgical smoke, and OSHA sets permissible exposure limits (PELs) to protect workers from the hazards associated with inhaling benzene. Protection from inhaling benzene is mandated by OSHA because benzene is documented as being a trigger for leukemia.[26]

Awareness of some of the chemical components of smoke, recommended exposure limits, and associated health effects are important considerations when educating surgical staff members. Along with OSHA's PELs, NIOSH sets relative exposure limits (RELs) and the American Conference of Governmental Industrial Hygienists (ACGIH) sets threshold limit values (TLVs) of toxic chemicals (Table 3).

Other components. In addition to concerns about the chemical components of surgical smoke, concerns have been raised about the presence of blood particles, viruses, and bacteria in the smoke particulate matter. Plappert et al[27] designed a study aimed at evaluating the cytotoxic, genotoxic, clastogenic, and mutagenic potential of the byproducts of laser pyrolysis of tissue (ie, in which the tissue is exposed to very high temperatures).[28] After subjecting the aerosols to several laboratory tests, the research team reported that they

> *were able to prove that the particulate fraction of laser pyrolysis aerosols originating from biological tissues undoubtedly have to be classified as cytotoxic, genotoxic, clastogenic, and mutagenic.*[28(p1)]

They warned that OR personnel should be protected from the health hazard of surgical smoke.

The potential of viral and bacterial transmission to health care workers consistently has received the attention of researchers. In 1998, Capizzi et al[29] studied the viability of bacteria during laser resurfacing. Specimens were collected and tested after 13 procedures. Of the 13 bacterial cultures, five had coagulase-negative *Staphylococcus* growth. Of the five, one also grew *Corynebacterium* and one grew *Neisseria*. The researchers concluded that there was potential for transmitting bacteria to OR personnel and that a smoke evacuation system should be used.[29]

Garden et al[30] documented the same concerns about surgical smoke and determined that smoke plume transmits disease. The topic of human papilloma virus (HPV) and HIV infectivity was investigated by several groups as early as the late 1980s and 1990s. The researchers determined that pathogens capable of transmitting disease were present in surgical smoke.[31,32]

In spite of the pervasive smell at a distance from the surgical site, a common belief is that the scrubbed members of the surgical team are at greater risk from inhaling the smoke and those further away are less at risk.

How Smoke is Distributed in the OR

There is no doubt that the smell of surgical smoke can permeate an entire surgical suite. In spite of the pervasive smell at a distance from the surgical site, a common belief is that the scrubbed members of the surgical team are at greater risk from inhaling the smoke and those further away are less at risk. A decade ago, Brandon and Young[33] conducted studies to determine the particle size and distribution of smoke in the OR. Their results revealed that without smoke removal, particle concentration can increase from a baseline of approximately 60,000 particles per cubic foot (cu ft) to about one million particles per cu ft within five minutes after the ESU is activated. The concentration levels remain elevated throughout the duration of ESU use. High concentrations also were documented throughout the OR, indicating that everyone in the OR is subjected to particle concentrations comparable to those to which scrubbed team members are exposed. The researchers further documented that it took about 20 minutes for OR ventilation to return the room air to baseline particle levels.[33]

TABLE 3
Chemicals Present in Surgical Smoke

Acetaldehyde
OSHA PEL*: 200 parts per million (ppm)
ACGIH TVL**: STEL#: 25 ppm (A3 carcinogen)
NIOSH REL##: Carcinogenic without further association
Health effects: Eye, skin, and respiratory irritant. Clinical exposure to vapors also include erythemea, coughing, pulmonary edema, narcosis. May be teratogenic. Irritation can be expected after 50 ppm for 15 minutes. May facilitate uptake of other atmospheric contaminants by bronchial epithelium.

Acrolein
OSHA PEL: 0.1 ppm (0.25 mg/m^3)
NIOSH REL: 5 mg/m^3
Health effects: Eye, skin, upper respiratory tract irritant. May increase blood clotting time and cause liver and kidney damage.

Acetonitrile
OSHA PEL: 40 ppm
ACGIH TVL: 40 ppm
Health effects: Nose irritant, throat asphyxiant. Has caused liver and kidney damage in animal models.

Benzene
OSHA PEL: 1 ppm (3 mg/m^3)
ACGIH TVL: 10 ppm (32 mg/m^3)
NIOSH REL: 0.1 mg/m^3
Health effects: Headache, weakness, appetite loss, and fatigue. May cause bone marrow damage, injury to blood-forming tissue from chronic low-level exposure. The threshold value limit of parts per million inhaled intermittently over one year may alter nutritional status and gross metabolism.

Formaldehyde
OSHA PEL: 0.75 ppm (2.5 mg/m^3)
ACGIH TVL: STEL: 2 ppm (15 minutes) (A3 carcinogen)
Health effects: Eye, nose, throat, and respiratory system irritant. Exposure may cause cough and bronchospasm. Sensitizer. Shown to cause nasal tumors in rats.

Polyaromatic hydrocarbons (naphthalene)
OSHA PEL: 10 ppm (naphthalene)
ACGIH TVL: 10 ppm (naphthalene); STEL: 15 ppm
Health effects: Absorbed via respiratory tract. Ocular, respiratory irritant. Wide range of sensitivity. Effects noted in very low doses. Exposure likely occurs via particle inhalation. Styrene and acrolein may increase inhalation effect.

Styrene
OSHA PEL: 100 ppm (ceiling 200 ppm; peak 600 ppm) (5 minutes)
ACGIH TVL: 213 ng/m^3 = 50 ppm
Health effects: Respiratory irritant. Short-term vapor exposure in animal studies found damage to the lining of the nose.

Toluene
OSHA PEL: 200 ppm (ceiling 200 ppm; peak 600 ppm)
ACGIH TVL: 50 ppm
NIOSH REL: 100 ppm; STEL: 150 ppm
Health effects: Well absorbed via inhalation. Vapors irritate eyes, respiratory tract. Extensive documentation of effects in animal models, many related to central nervous system functions. High levels associated with teratogenesis.

Xylene
OSHA PEL: 100 ppm; STEL: 150 ppm
ACGIH TVL: 100 ppm
Health effects: Well absorbed via respiratory tract. Respiratory tract irritation begins at 200 ppm. Chronic exposure associated with reversible changes in red and white blood cell counts and increases in platelet counts.

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** Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL)*
*** American Conference of Governmental Industrial Hygienists (ACGIH) threshold value limit (TVL)*
 # Short-term exposure limit (STEL)
National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL)

The results of a 2002 study by Nicola et al[34] helped explain how all surgical team members could be exposed to similar levels of surgical smoke. They measured the speed and distance that smoke particles were ejected from lasered animal skin. Laser Doppler velocimetry measured the speed of smoke particles to be in the range of 9 to 18 m per second. When the particles were set in motion, the residual kinetic energy could send the particles about 0.87 m from the skin surface.

Tanpowpong and Koytong[35] compared suspended particulate matter in an office with

laser smoke particles in a laser OR. Suspended particles in the 15 micrometer, 10 micrometer, and 2.5 micrometer size were measured using a laser diode dust monitor. All three particle sizes were within safe levels when measured in the office. The levels of suspended particles in the OR before laser use were higher than measurements in the office. The levels of suspended particulate matter during and after laser use were much higher and were deemed to be dangerous to both OR personnel and patients.

Risks to OR Personnel

For many years, there has been interest in determining and defining exactly what hazard surgical smoke represents. What are the risks of inhaling surgical smoke? Are the potential dangers cumulative? Although, there is an abundance of both anecdotal information and recommendations, a specific link between exposure to surgical smoke and adverse health effects to perioperative personnel has not been made. There are no mandatory regulations in the United States that surgical smoke must be evacuated, but the voluntary standards from professional organizations clearly indicate that a potential danger exists if personnel continuously inhale substances present in surgical smoke.

Alp et al[36] developed a list of potentials risks (Table 4). The symptoms and potential risks identified are consistent with reports from health care professionals and researchers during the past two decades.[30,37-40]

Risks to Patients

Surgical smoke has long represented a potential risk for patients during laparoscopic surgery. A study from the University of Minnesota, Minneapolis, measured levels of carbon monoxide inside the peritoneal cavity during laparoscopic cholecystectomy.[41] The study found that carbon monoxide was present in the abdomen five minutes after the use of electrosurgery at a median concentration of 345 parts per million (ppm). By the end of the procedure, the median concentration had risen to 475 ppm. These measurements were in excess of the 35 ppm upper limit for a one-hour exposure set by the US Environmental Protection Agency.

Table 4
Risks of Surgical Smoke[1]

Acute and chronic inflammatory respiratory changes (eg, emphysema, asthma, chronic bronchitis)
Anemia
Anxiety
Carcinoma
Cardiovascular dysfunction
Colic
Dermatitis
Eye irritation
Headache
Hepatitis
HIV
Hypoxia or dizziness
Lacrimation
Leukemia
Lightheadedness
Nasopharyngeal lesions
Nausea or vomiting
Sneezing
Throat irritation
Weakness

1. Alp E, Bijl D, Bleichrodt RP, Hansson A, Voss A. Surgical smoke and infection control. J Hosp Infect. *2006;62(1):1-5.*

Danger of smoke inside the abdomen also was documented nearly 15 years ago at the Mercer University School of Engineering, Macon, Georgia.[1] As smoke is produced inside the abdomen, it is absorbed through the peritoneal membrane. The subsequent result in the patient's blood stream is an increase in methemoglobin and carboxyhemoglobin concentrations, thereby reducing the oxygen carrying capacity of red blood cells. The potential hazard for the patient is falsely elevated pulse oximeter readings because pulse oximeter readings are compromised in the presence of dyshemoglobinemia. Carboxyhemoglobin and methemoglobin are dyshemoglobinemias, which produce a falsely elevated oxygen reading that could result in unrecognized patient hypoxia.

The Best Defense Against Surgical Smoke

What can health care workers do to protect themselves from the potential dangers of inhaling surgical smoke? Former *AORN Journal*

editor, Brenda Gregory Dawes, RN, MSN, CNOR, stated in 2000 that a "stop smoke campaign begins with you."[42(p768)] Dawes recommended that perioperative nurses become experts in what can be done and use available tools and knowledge to minimize exposure to surgical smoke.

General OR ventilation. Air exchanges in the OR through general air circulation should be maintained at a minimum of 15 exchanges per hour in US hospitals. All rooms should be maintained at positive pressures.[10] It also is important to ensure that the filters for the general ventilation system are maintained and changed as recommended by the manufacturer of the system. Dirty air filters will impede room air exchanges.

Surgical masks. The original purpose of the surgical mask was to protect patients from infections harbored by members of the surgical team. There also is a need to protect health care professionals from aerosols released into the atmosphere from surgical smoke. The filtration efficiency of masks varies. Surgical masks generally filter particles to about 5 micrometers in size. High-filtration masks, also referred to as laser masks, filter particles to about 0.1 micrometers in size. Approximately 77% of the particulate matter in smoke is 1.1 micrometers and smaller.[43] Although wearing the high-filtration masks affords some respiratory protection, viral particles can be much smaller than 0.1 micrometers. Furthermore, there is ongoing controversy about how masks are worn as well as how long surgical masks should be worn. A mask worn loosely or worn too long is less effective.[44] Masks should be worn snugly and changed often. Masks should not, however, be the only defense against surgical smoke. Additional means are necessary to protect surgical team members from inhaling surgical smoke.

Wall suction. Wall suction in the OR is the simplest way to evacuate smoke. Wall suction usually pulls less than 5 cu ft per minute, so it will only be effective on procedures that produce a small amount of smoke. If wall suction is used, an in-line filter also should be used; surgical team members have no protection if an in-line filter is not used to filter the smoke. For wall suction to be effective, the suction lines and filters outside the OR also must be kept clear. In-line filters must be used according to the manufacturer's instructions and changed as recommended, because an overused filter affords no protection. After use, in-line filters should be disposed of in accordance with standard precautions.

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Portable smoke evacuation systems. Portable smoke evacuation systems currently are the most versatile choice for ORs. The most effective smoke evacuation system is the triple-filter system equipped with an ultra-low particulate air (ULPA) filter. These filters are made up of a depth media material capable of capturing 0.12 microns of particulate matter at an efficiency rate of 99.9999%. At that rate, only one in one million particles will escape capture.[26]

The system includes a prefilter that captures large particles. The ULPA filter is the second stage of the filter, and it captures the smaller particle components of smoke. The final filter is composed of a special charcoal that captures the toxic chemicals found in smoke. Triple filter systems normally have variable suction volume capacity to accommodate various levels of smoke production. An effective, portable smoke evacuation system should be able to pull 30 cu ft to 50 cu ft per minute to be able to capture surgical smoke.

A variety of capture devices can be used with portable smoke evacuation systems. A small carriage unit that attaches to the ESU pencil allows for smoke capture almost at the site of its generation. The ECRI recommends that the capture device be placed within 2 cm of the point of smoke production (Figure 1).[16] Larger-sized tubing also

can be used with smoke evacuators when it is not feasible to use the pencil-carriage device.

The larger tubing can be used farther away from the site of electrosurgery, but care should be taken to ensure that the tubing is close enough to capture smoke effectively. The larger tubing also requires that the evacuator produce greater capture velocity, thereby creating more noise from the system. Perioperative staff members should anticipate the amount of smoke that will be produced during the procedure and choose the system most appropriate for the procedure. Standard precautions should be taken after a procedure when discarding the disposable products used for smoke evacuation.

Central smoke evacuation systems. Newly constructed ORs often install a central smoke evacuation system. These systems are situated outside the OR and, therefore, are quieter than portable systems. Although stationary systems are expensive, they usually are more powerful than portable systems.[45]

Laparoscopic smoke evacuation. Surgical smoke also should be evacuated and filtered during laparoscopic procedures. Smoke buildup during minimally invasive procedures can hinder the surgeon's view. Using devices that produce less smoke, such as bipolar ESUs or tissue fusion systems, can help reduce smoke production.[46] Laparoscopic smoke also can be evacuated and filtered through special laparoscopic smoke evacuation devices. In addition to allowing better visibility during surgery, evacuating smoke reduces the amount of methemoglobin and carboxyhemoglobin in the patient's bloodstream. When the pneumoperitoneum is released at the end of the procedure, it also should be evacuated and filtered through a smoke evacuation system to prevent spewing of abdominal contents into the faces of surgical team members.

Recommended Practices, Guidelines, Standards, and Regulations

The air quality in ORs around the world has been a cause for concern for more than three decades. Evacuation of surgical smoke is not mandated by any organization that has the force of law behind it. Many organizations, however, have set voluntary guidelines and professional standards in an effort to protect health care professionals from surgical smoke. A review of current recommendations can assist perioperative practitioners in setting up policies and procedures for individual institutions. The combined resources available from these agencies and organizations can be a strong support for perioperative practitioners.

The ACGIH. This voluntary organization is concerned with issues related to air quality and exposure to potentially harmful contaminants. The ACGIH has set TLVs for exposure to some known carcinogens and other potentially harmful compounds. Although the TLVs are not binding requirements for any organization, they are recognized as a resource to help resolve problems related to environmental air quality.[47]

The ANA. The ANA has been a partner with AORN on the issue of surgical smoke since AORN's major initiatives began in 1996. The ANA has urged nurses to be proactive in working with government officials to develop specific smoke guidelines and has contacted government officials, including those at OSHA,

Figure 1 • Electrosurgical unit pencil with smoke evacuation attachment. ***Illustration courtesy of Covidien, Boulder, CO.***

to push for stronger controls.[48]

AORN. AORN has been a strong proponent for protection from surgical smoke and has published the recommendation to filter and evacuate surgical smoke since 1994.[49,50] AORN held national conferences on surgical smoke more than a decade ago in 1996 and 1997 to raise awareness about the issues surrounding surgical smoke and to facilitate adoption of standards and guidelines from partner organizations. Recommended practices on surgical smoke in the laser, electrosurgery, and ultrasonic sections of *Perioperative Standards and Recommended Practices* state that surgical smoke should be evacuated and filtered.[51-53] AORN's recommended practices are used in ORs around the world to set standards for the perioperative care environment.

An alliance with OSHA to collaborate on workplace safety issues is another avenue AORN is pursuing to make the OR environment safer for workers and patients.[54] AORN partners with many organizations working for the safety of not only its 40,000 members, but for anyone who provides care wherever operative and invasive procedures are performed.

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THE AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI). The ANSI is a multidisciplinary group of professional societies, trade associations, and other organizations that have developed voluntary standards focused on ensuring the safety and health of consumers and protecting the environment. This organization has published standards related to the safe use of lasers and has supported the use of smoke evacuation in its ANSI Z136.3 standard *Safe Use of Lasers in Health Care Facilities*.[55]

NIOSH. As part of the Centers for Disease Control and Prevention (CDC) within the US Department of Health and Human Services, NIOSH investigates potential occupational health risks and makes recommendations to OSHA. Although NIOSH has no regulatory or enforcement authority, it does conduct health hazard evaluations and issue *Hazard Alerts.* The NIOSH recommendations on smoke evacuation are referenced on the OSHA web site. After AORN's 1996 smoke conference, at which NIOSH was represented, the strongest recommendation to date was issued. The NIOSH *Hazard Alert* on the control of smoke from laser and electrosurgical procedures is one of the most important documents available to health care professionals because it recommends evacuation and filtration of surgical smoke. The *Hazard Alert* has remained on the NIOSH web site since its development in 1996. It can be accessed at *http://www.cdc.gov/niosh/hc11.html.*

THE ECRI. This nonprofit agency evaluates products used in health care; makes recommendations about the safe use of those products; and provides consultation, evaluation, and educational services to health care organizations. The ECRI has consistently recommended the use of smoke evacuation and filtration while acknowledging there is no national regulation requiring compliance. Nevertheless, the ECRI believes that it is prudent for facilities to minimize staff member exposure to surgical smoke.[45]

THE JOINT COMMISSION. The Joint Commission, founded in 1951, evaluates health care organizations and programs and accredits facilities that meet its requirements. Hospitals voluntarily seek accreditation from the Joint Commission because this essentially alerts the public that the hospital complies with safe standards in delivering patient care. In 2004, the Joint Commission entered into an alliance with OSHA to work together in addressing safety and health issues in health care facilities. The agreement between OSHA and the Joint Commission focuses on reducing exposure to biological and

airborne hazards in health care.[56]

OSHA. Although OSHA is an agency of the federal government charged with enforcing laws and regulations that provide employees in the United States with a safe and healthy working environment, OSHA does not have specific regulations related to the evacuation of surgical smoke. Officials at OSHA consistently have stated that regulations already exist to protect workers from surgical smoke. The OSHA General Duty Clause and the standards for respiratory protection and protection from bloodborne pathogens are cited routinely by OSHA officials as those that should be used to enforce safe workplace standards, including smoke evacuation.

In 1998, an OSHA guideline on surgical smoke and laser and electrosurgical plume safety was added to the OSHA web site. Although the OSHA guideline was never released because OSHA believed that more research was needed, the protection recommendations mirrored those of the CDC/NIOSH *Hazard Alert*.

In December 2006, OSHA entered into an alliance with AORN to collaborate on workplace safety issues. One of the workplace issues on the agenda was safety from exposure to smoke plume generated from the use of ESUs and lasers.[54] Since that time, OSHA has added a Hospital eTools section to its web site, a portion of which addresses perioperative workplace safety. Information about the hazards of smoke plume are included in this area of the web site.[57]

Officials from the Occupational Safety and Health Administration cite the General Duty Clause and the standards for respiratory protection and protection from bloodborne pathogens as those that should be used to enforce safe workplace standards, including smoke evacuation.

Implementing a Smoke Evacuation Program

The first step in developing a smoke evacuation program is to make a facility-wide commitment to protect staff members and patients from the potentially harmful effects of surgical smoke. A team should be convened that consists of representatives from each of the professional groups providing or guiding care in the OR: surgeons, anesthesia care providers, circulating nurses, scrub persons, and administrators. Agreement from the entire surgical team before the program begins is vital and will help ensure success.

The team should evaluate available technology and select a smoke evacuation system that satisfies the comprehensive needs of the facility. Some points to consider when choosing one of the many available systems are

- cost and operating expenses,
- effectiveness,
- filter and canister design,
- filter monitoring,
- fluid removal capabilities,
- foot pedal activation versus automatic activation,
- noise production,
- single use versus reusable, and
- size.[58]

The team should develop policies and procedures based on the type of equipment being used because not all systems are the same. It is likely that both in-line suction filters and portable smoke evacuators will be needed. A helpful component of a smoke evacuation policy would be a delineation of which smoke evacuation system (eg, in-line, portable) is recommended for which surgical procedures (Figure 2). Policies should include competencies based on selecting and using accessories and smoke evacuation equipment.

Educating staff members about the hazards of surgical smoke is another key factor for success. Educators should take advantage of all available resources when designing education

FIGURE 2
Sample Smoke Evacuation Policy

Department:
Perioperative Services

Original date: 02/1994

Review dates: 05/1995
08/1999

Revision dates: 06/2007

Policy name:
Surgical Smoke Evacuation

Policy:
It is the policy of [Facility Name] that smoke plume generated during surgical procedures will be captured and disposed of via smoke evacuators or in-line filters.

Definitions:
None

Procedure/guideline:
1. During surgical procedures that generate a minimal amount of smoke, a 0.1-micron, in-line filter will be used with suction tubing that is no longer than 12 ft in length with a suction tip.
   A. In-line filters have a 10-hour smoke evacuation time limit or a one-day, single-use limit.
   B. Examples of procedures that require an in-line filter:
      Back procedures
      Breast biopsies
      Craniotomies
      Dermatological procedures
      Ear procedures
      Hand procedures
      Laparoscopies
      Nasal procedures
      Temporal artery biopsies
      Thorascopies
      Tonsillectomies
      Vocal cord polyp procedures
2. During surgical procedures that generate larger amounts of smoke, a smoke evacuation system with an evacuation hose will be used.
   A. Examples of procedures that require an evacuation system with an evacuation hose:
      Abdominal surgical procedures
      Breast procedures
      Excisional neck procedures
      Large extremity procedures
      Thoracic procedures
      Vaginal procedures
      Vaporization of condyloma

Attachments:
None

For more information contact:
Advanced technology coordinator

Approval bodies:
Perioperative Services

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programs to increase awareness of the dangers of surgical smoke and methods to minimize the inherent risks. After a system is selected and the equipment and supplies are available, inservice programs should be conducted on the use of equipment. This education usually is provided by representatives from the manufacturer of the equipment because they know the equipment best.

As with any new practice, team members should monitor compliance. Monitoring is part of evaluation and needs assessment. It takes time to replace old habits with new ones, and without compliance monitoring, old habits quickly reappear. If compliance with using smoke evacuation is low, this could indicate a need for additional education. Teamwork and peer support are essential components for monitoring compliance. Using a standardized form can help make the process easier.

ELIMINATING A CONTROLLABLE HAZARD

Acting to eliminate a controllable hazard such as smoke can only help minimize health costs and improve the health of perioperative personnel and their patients. Hospitals that can advertise a smoke-free work environment in the OR might have an edge in recruiting and retaining top perioperative staff members as the population of nurses ages and the pool of professional nurses continues to shrink. Efforts to control this environmental occupational hazard, ultimately,

can be very beneficial to staff members and patients. – AORN –

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No Superior Prostate Cancer Treatment

A new report concludes that scientific evidence has not established surgery or any other single treatment as the superior treatment for all men with prostate cancer, according to a February 4, 2008, news release from the Agency for Healthcare Research and Quality. In 2007, approximately 218,000 men were diagnosed with prostate cancer, and approximately 27,050 of these men died from the disease. The primary goals of treatment are to determine whether an intervention is needed to prevent death and disability and to minimize complications. Treatment choices often take into account a patient's age, race, ethnicity, health status, family history, preferences, and how quickly the cancer is likely to spread.

The report, based on a review of 592 published articles, compares the effectiveness and risks of eight prostate cancer treatments, including surgical removal of prostate and surrounding tissues, minimally invasive surgery to remove the prostate, external radiation, radioactive implants, destruction of cancer cells through rapid freezing and thawing, removal of testicles or hormone therapy, high-intensity ultrasound, and "watchful waiting." The report is intended to provide unbiased, evidence-based information so that patients, clinicians, and others can make the best treatment decisions.

Outcomes vary for prostate cancer patients choosing surgery; overall, no treatment proven superior [news release]. Rockville, MD: Agency for Healthcare Research and Quality; February 4, 2008.

The Hazards of Surgical Smoke

Purpose/Goal

To educate perioperative nurses about the hazards of surgical smoke, the tools available to minimize exposure to smoke, and efforts of professional organizations to reduce the exposure risk to perioperative personnel and their patients.

Behavioral Objectives

After reading and studying the article on the the hazards of surgical smoke, nurses will be able to

1. describe surgical smoke,

2. identify devices that cause surgical smoke,

3. explain the risks of surgical smoke to perioperative personnel,

4. describe options for decreasing the risk of surgical smoke, and

5. discuss the efforts of professional organizations to regulate the evacuation of surgical smoke.

Questions

1. Surgical smoke
1. results from the interaction of tissue and mechanical tools or heat-producing equipment.
2. is caused by tools used for dissection and hemostasis.
3. results from incorrect use of surgical tools.
4. is a gaseous by-product of the disruption and vaporization of tissue protein and fat.

a. 1 and 3
b. 2 and 4
c. 1, 2, and 4
d. 1, 2, 3, and 4

2. One of the goals of AORN's second conference on smoke in February 1997 was to
a. increase consensus on best methods to effect change in the regulation of surgical smoke.
b. draft national legislation requiring surgical smoke to be evacuated in all perioperative settings.
c. discuss ways to influence smoke evacuation manufacturers to improve the technology.
d. create sanctions that would be imposed on facilities that do not adequately protect their personnel from surgical smoke.

3. Types of heat-producing devices used during surgical procedures include
1. high-speed burrs, drills, and saws.
2. electrosurgical units.
3. lasers.
4. ultrasonic devices.

a. 1 and 3
b. 2 and 4
c. 1, 2, and 3
d. 1, 2, 3, and 4

4. Surgical smoke is made up of water or steam and cellular debris in the form of particulate material that is composed of
1. bacteria.
2. blood and tissue particles.
3. chemicals.
4. viruses.

a. 1 and 3
b. 2 and 4
c. 1, 2, and 3
d. 1, 2, 3, and 4

5. Particles can be deposited in the bronchioles

and alveoli if they are smaller than _____ micrometers in size.
a. 2
b. 5
c. 20
b. 200

6. Everyone in the OR is subjected to particle concentrations comparable with those to which scrubbed team members are exposed.
a. true
b. false

7. Alp et al developed a list of potentials risks to perioperative personnel who continuously inhale substances present in surgical smoke. These risks include
1. anemia.
2. anxiety.
3. carcinoma
4. HIV.
5. kidney failure.
6. leukemia.

a. 1, 3, and 5
b. 2, 4, and 6
c. 1, 2, 3, 4, and 6
d. 1, 2, 3, 4, 5, and 6

8. If masks are worn snugly and changed often, they are effective as the primary defense against surgical smoke.
a. true
b. false

9. The following agencies and organizations have set voluntary guidelines and professional standards in an effort to protect health care professionals from surgical smoke:
1. the American Conference of Governmental Industrial Hygienists.
2. the American Nurses Association.
3. the American National Standards Institute.
4. AORN.
5. the Joint Commission.
6. the National Institute of Occupational Safety and Health.
7. the Occupational Safety and Heath Administration.

a. 1, 3, and 5
b. 2, 4, and 6
c. 1, 3, 4, 5, and 7
d. 1, 2, 3, 4, 5, 6, and 7

10. Some points to consider when choosing a smoke evacuation system are
1. effectiveness.
2. filter monitoring.
3. fluid removal capabilities.
4. foot pedal versus automatic activation.
5. noise production.
6. single use versus reusable.
7. size.

a. 1, 3, and 5
b. 2, 4, and 6
c. 1, 3, 4, 5, and 7
d. 1, 2, 3, 4, 5, 6, and 7

The behavioral objectives and examination for this program were prepared by Rebecca Holm, RN, MSN, CNOR, clinical editor, with consultation from Susan Bakewell, RN, MS, BC, director, Center for Perioperative Education. Ms Holm and Ms Bakewell have no declared affiliations that could be perceived as potential conflicts of interest in publishing this article.

This program meets criteria for CNOR and CRNFA recertification, as well as other continuing education requirements.

AORN is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center's Commission on Accreditation.

AORN is provider-approved by the California Board of Registered Nursing, Provider Number CEP 13019. Check with your state board of nursing for acceptance of this activity for relicensure.

Answer Sheet

3.0 CE

The Hazards of Surgical Smoke

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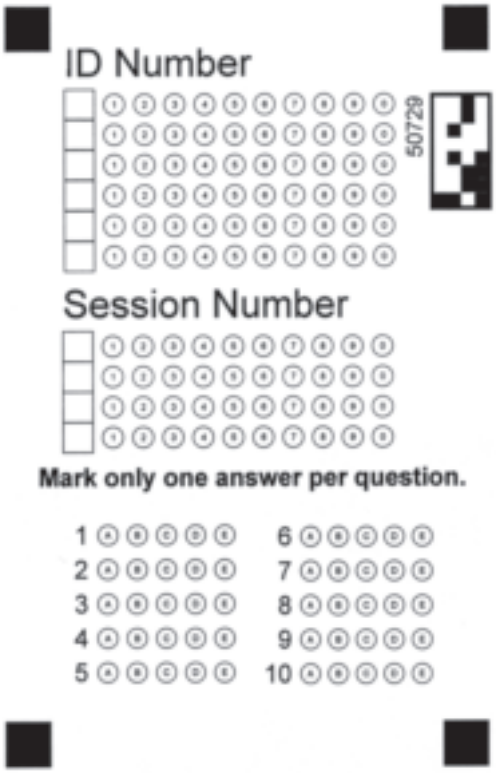

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3.0 CE Learner Evaluation

The Hazards of Surgical Smoke

THIS EVALUATION is used to determine the extent to which this continuing education program met your learning needs. Rate these items on a scale of 1 to 5.

PURPOSE/GOAL

To educate perioperative nurses about the hazards of surgical smoke, the tools available to minimize exposure to smoke, and efforts of professional organizations to reduce the exposure risk to perioperative personnel and their patients.

OBJECTIVES

To what extent were the following objectives of this continuing education program achieved?

1. Describe surgical smoke.
2. Identify devices that cause surgical smoke.
3. Explain the risks of surgical smoke to perioperative personnel.
4. Describe options for decreasing the risk of surgical smoke.
5. Discuss the efforts of professional organizations to regulate the evacuation of surgical smoke.

CONTENT

To what extent

6. did this article increase your knowledge of the subject matter?
7. was the content clear and organized?
8. did this article facilitate learning?
9. were your individual objectives met?
10. did the objectives relate to the overall purpose/goal?

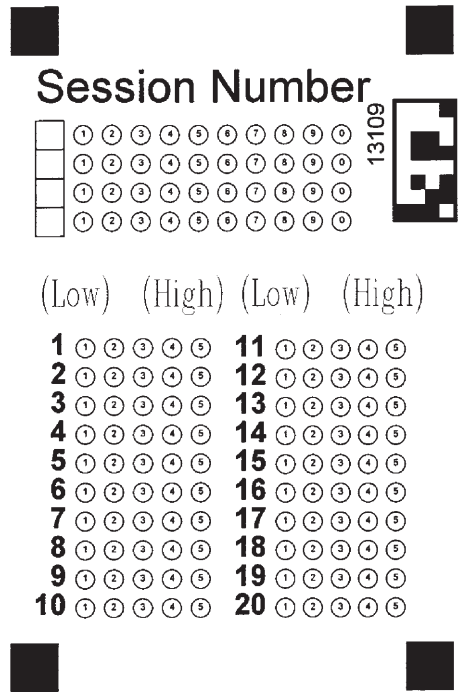
TEST QUESTIONS/ANSWERS

To what extent

11. were they reflective of the content?
12. were they easy to understand?
13. did they address important points?

LEARNER INPUT

14. Will you be able to use the information from this article in your work setting?
    1. yes
    2. no
15. I learned of this article via
    1. the *Journal* I receive as an AORN member.
    2. a *Journal* I obtained elsewhere.
    3. the *AORN Journal* web site.
16. What factor most affects whether you take an *AORN Journal* continuing education examination?
    1. need for continuing education contact hours
    2. price
    3. subject matter relevant to current position
    4. number of continuing education contact hours offered



What other topics would you like to see addressed in a future continuing education article? Would you be interested or do you know someone who would be interested in writing an article on this topic?

Topic(s): _____

_____

Author names and addresses: _____

_____

_____