Surgical Smoke: What Do We Know

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Many facilities have signage indicating that the facility is ñsmoke-free.ò When in fact, there remain many facilities that this is not true. For those facilities that do not evacuate surgical smoke, the perioperative team members are exposed to surgical smoke on a daily basis. There have been over three decades of concern related to health care workers chronic exposure to surgical smoke and potential untoward health risks. This presentation will present current evidence to allow you to formulate your own conclusions.

Surgical smoke is called a variety of names, including cautery smoke, diathermy plume, plume, smoke plume, aerosols, bio-aerosols, vapor and air contaminants. In the operating room, surgical smoke can be seen and smelled wherever surgical and/or invasive procedures are conducted. Surgical smoke and exposure for the healthcare worker is very common. Surgical smoke is the result of the interaction of tissue and mechanical tools and/or heat producing equipment such as those that are used for dissection and hemostasis. Both the visible and the odorous components of surgical smoke are the gaseous byproducts of the disruption and vaporization of tissue protein and fat (Ott, 1977).

Issue of Concern

The issue of exposure for health care workers and air quality in operating rooms around the world is not a new issue. It has been a cause for concern for more than three decades. Dr. Jane Rothrock summarized the progression of concern from exposure to surgical smoke from 1975 to 1995 (Rothrock, 2006). The contents of surgical smoke have been described at the very least as being a nuisance, and at worst carcinogenic. Since Mihashi raised concerns about the contents of surgical smoke in 1975, researchers and practitioners have continued to investigate surgical smoke, what is in it, and document findings.

Contents of Surgical Smoke

Contents of surgical smoke have been described as particulate matter that contains blood, and potentially infectious viruses and bacteria. An additional component is the various potentially hazardous chemicals found in surgical smoke. These chemicals are present during the care of perioperative patients. Examples of chemicals which health care workers are chronically exposed to include: acrolein, benzene, formaldehyde, toluene and polycyclic aromatic hydrocarbons (Sawchuck, 1989). Of all the chemicals that have been identified as being in surgical smoke, there is no evidence that supports the exposure as being ñgoodò for healthcare workers to inhale.

Why the Different Standard of Care for Application of Smoke Evacuation (Laser vs Electrosurgery)?

Health care workers for many years have raised the issue of why smoke plume is evacuated for laser procedures and not from smoke created from electrosurgery. Is there a difference? The answer is no, there is no difference. Thermal heat is produced with the use of both laser and electrosurgery units and spectral analysis of the content of laser and electrosurgery are similar based on particle size generated and the amount (ECRI, 1990). Because of the similarities, facility policies on smoke evacuation should be the same for electrosurgery units as it is for lasers (Ulmer, 2008).

How is Smoke Produced?

The primary mechanism to achieve hemostasis and tissue dissection during surgical procedures is with heat-producing devices. Examples of these include the electrosurgery unit, lasers, ultrasonic devices, high-speed drills, burrs and saws. All of these devices produce heat, which allows the surgeon to achieve the desired tissue effect. As heat is generated by the device the effects of tissue results in the gaseous byproduct of surgical smoke containing cellular content and debris that is released into the air. I will review some of the devices in greater detail.

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 sonic range of human hearing.

Ultrasonic aspirators have hollow tips. With a hollow tip, only the tissue in direct contact with the circumferential edge or core of the tip is impacted. Minimal thermal damage occurs because the heat generated by the tip is conducted away via the irrigation fluid. The tip irrigation does produce a fine mist but the surgical field is continuously cleared by the suction at the tip.

Ultrasonic scalpels use 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 (Siperstein, 2002). The motion of the tip produces a vapor which, because of lower tip temperatures, could carry infectious aerosols (Barrett, 2004).

An often overlooked source of air contamination in the operating room 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 do heat up, irrigation is often dripped 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. The next time you scrub on an orthopedic case, look closely at all of the debris that remains on the towels. This is debris that is contained in the air as well, increasing the exposure of the health care worker.

Particle Size and Dissemination

The issue of particle size is very important to understand as it relates to your protection and risks. Particle size can range from 0.1 ï 5.0 micrometers. Particles in the size of 5.0 micrometers or larger are deposited in the upper airway. Particles that are smaller and less than 2.0 micrometers in size are deposited in the bronchioles and alveoli. Of the surgical smoke or plume generated in the O.R., each technology produces a different particle size. The smaller the particle size, the farther it can travel, which can impact people circulating during a procedure as well as scrubbed team members (Karoo, 2004).

Equally important is the speed and distance which particles can travel. In the past it was felt that only team members at the direct surgery site were exposed. However research has proved that all member of the surgical team are exposed to similar level of surgical smoke. Nicola and associates in Brazil measured the speed and distance that smoke particles were ejected from lased animal skin. Laser Doppler velocimetry (LDV) measured the speed of smoke particles to be in the range of 9 to 18 meters per second. Once the particles were set in motion, the residual kinetic energy could send the particles about 0.87 meters from the skin surface (Nicola, 2002).

We all know that the smell of surgical smoke can permeate an entire surgical suite and beyond. Brandon and Young have conducted studies to determine the particle size and distribution of smoke in the operating room. Reported results reveal that without smoke removal, particle concentration can increase from a baseline of about 60,000 particles per cubic foot, to about 1 million particles per cubic foot within five minutes after the electrosurgery unit is activated. The concentration levels remain elevated throughout the use of the ESU. The concentrations were also documented as being high throughout the operating room indicating everyone in the operating room is subjected to particle concentrations comparable to those of scrubbed team members. They further documented that it took about 20 minutes for the operating room ventilation to return the room to baseline levels (Brandon, 1997).

Risks to Perioperative Personnel

The chemical composition of surgical smoke is well documented. Areas of concern are the associated health risks with the chronic exposure to these chemicals and adverse health effects. Many nurses complain of bronchial symptomatology such as chronic cough, wheezing, increased congestion, throat irritation, flairs in asthmatic symptoms, headache, fatigue and eye irritation with exposure to surgical smoke. Additionally, they directly correlate lessening symptomatology when they are not exposed to surgical smoke on a daily basis.

Some examples of the chemical contained in surgical smoke include 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, colorless and can also be absorbed into the lungs, through the skin and via the gastrointestinal

tract (Barrett, 2004). Awareness of some of the chemical components of smoke and the associated health effects is an important consideration in the education of surgical staff members.

The Best Defense Against Surgical Smoke

As a professional in the operating room you must be your own best advocate in protecting yourself. I will discuss current recommendations to minimize your exposure to surgical smoke that include global regulation recommendations, OR ventilation practices, smoke evacuation systems and education for the surgical team.

General Operating Room Ventilation. The operating room air exchanges through the general air circulation is recommended to be maintained at a minimum of 15 exchanges per hour in U.S. hospitals. All rooms should be maintained at positive pressures (AORN, 2008). It is also important to ensure that the filters for the general ventilation system are maintained and changed as recommended by the manufacturer of the system. This is an example of a dirty air filter, it will impede room air exchanges.

Surgical Masks. Many nurses erroneously feel that the surgical mask is protective as it relates to surgical smoke exposure. Surgical mask filtration efficiency varies and may filter from about 5.0 micrometers up to .1 micrometer sized particles. As originally discussed approximately 77 percent of particulate matter in smoke is 1.1 micrometers and smaller. There are variations on individual wear of masks. I have personally observed practices where the mask is applied very loosely offering no protection at all. Other observations include the mask that is dangling from the neck and worn repeatedly throughout the day. A mask worn loosely or worn too long is noted to be less effective (Ball, 2001). It is recommended that masks 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. Operating room wall suction is the simplest way to evacuate smoke. Wall suction usually pulls 3- 5 cubic feet per minute (CFM), and will only be effective on procedures that produce a small amount of smoke. If wall suction is used, an inline filter should also be used. If an inline filter is not used to filter the smoke, then there is no protection for surgical team members. For wall suction to be effective, the suction lines and filters outside the operating room must also be clear. Inline filters must be used according to the manufacturerôs instructions, and changed as recommended. An overused filter affords no protection. After use, disposal of inline filters should be in accordance with standard precautions.

Smoke Evacuation Systems. To effectively evacuate surgical smoke if is recommended the following three components be contained in any evacuation system: capture device, vacuum source and filtration systems.

The capture device must be of an appropriate size to facilitate evacuation of the surgical smoke. The recommendation is that the capture device be within 2 cm from the point of smoke

production. There are a variety of pencil carriage devices available. Also, larger size tubing can also be used with smoke evacuators. When using the larger tubing for evacuation, you can place it farther away from the electrosurgery pencil site provided it is adequately capturing smoke effectively. An effective smoke evacuation system, it should have the ability to pull 30-50 CFM to capture surgical smoke effectively. When implementing either the use of a pencil carriage device or tubing, I advise you to make it as seamless as possible for the surgeon. It should be adequate to capture the smoke while not interfering with the view of the operative site for the surgeon.

One example is an ULPA (ultra-low penetration air) Four Stage Filter System that provides four layers of filtration. These include: 1) Prefilter - captures large particles and some fluids, 2) ULPA filter ï captures small particles, 3) Activated carbon ï absorbs toxic gases and orders and 4) Final/Post filter ï is an expanded foam used to trap any activated carbon particles migrating out of the filter. When smoke passes through this ULPA filter system, it has an efficiency rate of 99.9999%.

Regulations. In the United States evacuation of surgical smoke is not mandated by any organization that has the force of law behind it, like the Occupational Safety and Health Administration (OSHA). There are, however, many organizations that have set voluntary guidelines and professional standards in an effort to protect healthcare professionals from surgical smoke. A review of current recommendations can assist perioperative practitioners in setting up policies and procedures in individual institutions.

OSHA. The Occupational Safety and Health Administration (OSHA) is a US governmental agency that estimates that 500,000 healthcare workers are exposed to surgical smoke and bio-aerosols each year. The OSHA contains a General Duty Clause that regulates workplace conditions by stating that each employer - shall furnish to each of his employees employment which is free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees. Public Law 91-596 Section 5:

ñEach employer ï

shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees;

(2) Shall comply with occupational safety and health standards promulgated under this Act.

(b) Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct.ò

NIOSH. The National Institute of Occupational Safety and Health is under the Centers for Disease Control, within the U. S. Department of Health and Human Services. NIOSH investigates potential occupational health risks and makes recommendations to OSHA. NIOSH has no regulatory or enforcement authority, but does conduct health hazard evaluations and issue health hazard alerts. The recommendations of NIOSH are referenced on the OSHA website on smoke evacuation. The NIOSH Hazard Control Alert on the Control of Smoke From Laser/Electric Surgical Procedures is one of most important documents available to healthcare professionals in the United States. It recommends evacuation and filtration of surgical smoke. The Hazard Control has remained on the NIOSH Web site since its development in 1996. It can be accessed at http://www.cdc.gov/niosh/hc11.html http://www.cdc.gov/niosh/hc11.html.

The Joint Commission. In the United States this is a significant newly required requirement from the Joint Commission which is a voluntary provider of accreditation to over 15,000 facilities in the United States. In the 2008 Publication of the Joint Commission Accreditation Programs for Hospitals in the Environment of Care chapter, smoke evacuation is mentioned for the first time. The Standard is EC.02.02.01: The [organization] manages risks related to hazardous materials and waste. The standard references elements of performance in #9 stating that the hospital minimizes risks associated with selecting, handling, storing, transporting, using, and disposing hazardous gases and vapors. The note states that gases and vapors from cauterizing equipment and lasers as part of the hazardous materials that must be managed by hospitals. The Joint Commission has never before looked at any hazards associated with smoke.

Canada. The Canadian Standards Association (CSA) is an organization that collaborates with and sets standards for healthcare workers in Canada. The CSA published specific and detailed standards on plume scavenging in surgical, diagnostic, therapeutic and aesthetic settings that are very prescriptive on the need to evacuate and filter plume. The Standard: CSA Z305.13.09 can be accessed at http://www.csa.ca/Default.asp?language=english (CSA, 2009).

United Kingdom. The British Occupational Hygiene Society (BOHS) has published a guidance document on surgical smoke alerting healthcare organizations that surgical smoke represents a potential hazard to workers and should be evacuated and filtered. The guidance document can be accessed at http://www.bohs.org/resources/res.aspx/Resource/filename/529/Surgical_smoke.pdf.

Nordic Countries. The smoke guidelines for the Nordic countries are some of the most prescriptive published. The translated guidelines state: ñComparisons between laser smoke and diathermy smoke (electrocoagulation) show that even diathermy smoke can contain insanitary substances, and measures should be taken to eliminate such smoke. ñ

Conclusion

Today, my goal for this scientific presentation is to provide you information of what we know about surgical smoke, the associated health risks and current global recommendations and

regulations. I encourage each of you to advocate by promoting a smoke free work place environment for you, the surgical staff and for our patients.

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