SMOKE HAZARDS

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CHARACTERIZATION AND REMOVAL OF ELECTROSURGICAL SMOKE

Harold J. Brandon and V. Leroy Young

Electrosurgical smoke has been recognized as a definite nuisance in the OR for at least a decade, and several studies imply that viable human bloodborne pathogens can be transferred via smoke plume particulate. These particulates include not only HIV and human papilloma virus, but the probably more pervasive hepatitis and increasingly antibiotic-resistant tuberculosis.

Though investigators of electrosurgical smoke have so far been unable to identify substances classified as deleterious in other environments, the acknowledged ill effects of the plume have prompted widespread use of smoke evacuation devices. Our studies investigate the size and dispersive aspects of the plume and the efficacy of various smoke evacuation devices. Earlier reported results indicate that, with no smoke removal, particulate concentration increased from the baseline (typically near 60,000 particles per cubic foot) to approximately one million per cubic foot approximately five minutes after electrocautery commenced for breast reduction. The concentration remained there with minor variations until electrocautery was complete. In addition, our earlier results indicate that concentration levels are this high throughout the OR—all OR occupants are subjected to a particle concentration comparable to that of the surgeon. It takes approximately 20 minutes for the OR ventilation system to return particle concentrations to the original baseline level.

MATERIALS AND METHODS

In this current study, we measured particle concentrations of electrosurgical smoke using a laser particle counter capable of differentiating and counting particles in a range of sizes. Particulate counts are given in numbers of particles in the air sampled at the particle counter flow rate of 1 cubic foot per minute (cfm) and are available both as numbers of particles in each size range (ie, differential concentration) and as number of particles in all ranges (ie, cumulative concentration).

We obtained particle counts during several mammoplasty-related procedures: breast reduction—long considered a worst-case smoke-generating procedure—and breast implant removal and replacement. We conducted several experiments while the same surgical team performed these disparate procedures in succession on a single patient during a single session. The surgical procedures typically involved approximately 60 minutes of electrocautery, during which smoke production was more-or-less constant, with few periods of interruption. Time intervals reported in this article refer to the electrocautery session(s), not to the surgical procedure in toto, and are measured from the initiation of cutting.

Four smoke removal systems were evaluated—one that has a smoke removal tube attached to the electrosurgical device (ie, system #1) and three smoke removal systems with smoke removal tubes held at the point of generation by an OR assistant, so that pickup is under active agent control (ie, systems #2, #3, and #4).

RESULTS

Figure 1 shows additional cumulative particle concentration data, obtained during this study, for breast reduction with no smoke removal. The observed cumulative particle concentration profile verifies our previous results.

Figure 2 shows the cumulative particle concentration trace during a combination breast reduction/implant removal and replacement, performed sequentially during a single session (the time of change-over from the breast-reduction side to the implant side is not noted), while smoke removal system #1 was employed. Though particle
TABLE 2: SMOKE EVACUATION POLICY AND PROCEDURE

Policy:
It is the policy of the Gwinnett Hospital Systems that the smoke plume generated during surgical cases be captured and disposed of via smoke evacuators or in-line filters.

Purpose:
To protect patients and perioperative personnel from cross-contamination and inhalation of possible viable and/or hazardous particulate matter during surgical interventions.

Procedure:
1. On surgical procedures that generate a minimal amount of smoke, a 0.1 micron in-line filter will be used with a suction tubing no longer than 12 ft. in length with a suction tip. This is a single-use product. (See Appendix A).
2. On surgical procedures that generate greater amounts of smoke, a smoke evacuation system with an evacuation hose will be used. (See Appendix B).
3. Smoke evacuation hook-up.
   (1) Connect a corrugated tubing to the evacuator.
   (2) Hold tubing as close to the surgical site as possible to evacuate smoke.
   (3) Fluid may be evacuated by connecting to a 6 ft. tubing and suction tip to a reducer cap on the corrugated tubing. The surgical tip should be held as close to the surgical site as possible without interfering with the surgeon’s access to the operative site.
4. Associates will receive in-service training during orientation and yearly thereafter on proper hook up of the evacuation system.

Appendix A—Examples of procedures that require an in-line filter:
- Temporal artery biopsy
- Vocal cord polyps
- Laparoscopies
- Dermatological procedures
- Thoracoscopy
- Hand procedures
- Tonsillectomies
- Ear procedures
- Nasal procedures

Appendix B—Examples of procedures that require a smoke evacuation system with an evacuation hose:
- Abdominal surgical procedures
- Breast procedures
- Large extremity procedures
- Back procedures
- Cranietomies
- Thoracic procedures
- Vaporization of condyloma
- Vaginal procedures
- Excisional neck procedures


Follow-up

Follow-up is done on a routine basis by using peer observation to evaluate compliance (Table 1). If the data reflects that personnel are not complying, staff members and/or physicians attend an in-service program related to the specific issue. The policy and procedures are shown in Table 2. The careful choice to provide education and data, administrative support, policy implementation methods, and careful equipment selection made implementation a success. As health care professionals, we need to minimize the potential risks of transmission of any type of disease or pathology. With these safety measures in place, staff members and physicians feel they are adequately protecting themselves.

2. Ibid.

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devices mounted on the ESU device do not totally eliminate particulate. In general, reductions are greater than 50%, but with significant deviations both upwards and downwards. Possible reasons for the large increases in particle concentration include

- blockage of the smoke removal tube with tissue or residue,
- removal of the tube while significant particulate is still escaping from the electrocautery site, and
- an unfavorable orientation of the tube relative to the plume.

Figures 3 through 5 suggest that hand-held smoke removal systems are not significantly better than smoke evacuation tubes attached to the electrocautery device. Figures 3 and 4 also suggest that hand-held systems may not produce a constant level of smoke reduction, but rather a lower average level, with occasional episodes of large increases in particle concentrations. (This is similar to the results obtained with a system using a smoke evacuation tube attached to the electrocautery device.) These episodes of degraded operation occur at random, but the instances of lower particle concentrations suggest that these favorable operating conditions are possible and lower levels could be achieved more consistently.

**Conclusions and Recommendations**

For all smoke removal systems tested so far, significant particulate remained throughout the OR. Further studies are needed to determine the parameters that influence the efficiency of smoke removal systems. The operation of all available smoke removal systems should be investigated in a clinical setting, under as identical conditions as possible. The relationship between particle size and viability should be investigated, although earlier studies confirm the viability of filter-retained particulate.

The effectiveness of current surgical masks in filtering out smoke particles also should be investigated. △

2. D E Fry, “Reduction of HIV transmission during laparoscopic procedures,” (Guest editorial) Surgical Laparoscopy and Endoscopy 3 no 1 (February 1993).
5. Ibid.
6. Ibid.
7. Ibid.

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SMOKE VS. THE PEOPLE
Setting Up a Smoke Safe Environment

Vangie Paschall

IN BRIEF
△ This article chronicles one hospital’s efforts to set up an OR environment safe from the hazards associated with surgical smoke.
△ It traces the data collection phase, education process, product selection methods, and training steps taken by hospital staff members.

Inhalation of smoke during surgical procedures became an employee health issue when lasers were introduced in the OR. Health care facilities followed the standards of practice for laser smoke evacuation as recommended by the American National Standards Institute (ANSI) and the Association of Operating Room Nurses, Inc. (AORN). When a health care facility purchased a laser, a smoke evacuator was routinely included. Implementing recommended practices in the OR was not difficult. Surgeons and OR staff members learned about the hazards of laser smoke exposure, and routine use of smoke evacuators was implemented with few complaints. As more studies became available, concerns about surgical smoke in general emerged. These concerns are shared by leading safety organizations, such as ECRI and the National Institute for Occupational Safety and Health (NIOSH).

Avoiding difficulty when implementing safe surgical smoke evacuation depends on health care professionals’ understanding of the need for proper protection. In an atmosphere of downsizing and managed care, it can be difficult to justify evacuation costs to administrators and OR personnel. Often, the justification for not implementing safe practices is that outcome studies have not been quantified and no direct correlation between injury or death and surgical smoke has been made. Strong evidence suggests that surgical smoke is hazardous to the health of the surgical team. Implementing evacuation practices for the safety and health of OR staff members and patients is imperative.

EDUCATING STAFF MEMBERS ABOUT HAZARDS
Surgical staff members should have a basic understanding of the components of surgical smoke. After smoke constituents are understood, delivering the message and implementing the safe practice becomes the most difficult step. New evidence suggests there is little difference between smoke generated during laser procedures and smoke generated during electrosurgical device use. Both contain carcinogenic tissue, bloodborne pathogens, and carcinogens. In 1987, researchers identified the physiological effects associated with surgical smoke inhalation. The study found that animal models, when exposed to surgical smoke that was not properly evacuated, showed an accumulated particulate matter in their lungs which caused interstitial pneumonia, bronchitis, and emphysema. One year later, the same researchers verified the value of smoke evacuation by showing that animal models that received air filtered through an evacuator equipped with an ultra low penetrating air filter experienced no pathological changes over the course of the study. During other studies conducted in 1987, researchers found living human papilloma virus in CO₂ laser smoke and concluded that the thermal effects of lasers and electrosurgery may not destroy all the viable DNA in the viruses. Further studies have shown the presence of HIV DNA in smoke particulate matter. There has been no evidence of health care workers being infected with these viruses because of smoke exposure; however, the possibility of disease transmission through surgical smoke has captured the attention of regulatory agencies.

RECOMMENDED PRACTICES
The responsibility for setting safe standards of practice for health care providers lies with ANSI, which supports the idea that exposure to airborne contaminants during laser procedures presents a health hazard. As a result, ANSI recommends that smoke be removed by localized exhaust ventilation. Specific recommendations based on the constituents and mutagenicity of surgical smoke also have been made by NIOSH. According to NIOSH, smoke evacuation should be used to reduce the potential of exposure and chronic health effects. An independent medical device test organization has issued statements stating that electrosurgical smoke exposure and laser smoke exposure present the same dangers. The positions of these organizations and regulatory agencies make it clear that surgical smoke should be evacuated.

One of the controversies involving surgical smoke is whether the Occupational Safety and Health Administration’s (OSHA) regulatory standards regarding surgical smoke indicate that exposure to surgical smoke is hazardous to the OR team. Without OSHA regulatory standards in place, institutions often are reluctant to implement costly safe practices. What is OSHA’s position on smoke evacuation within
the surgical suite? The bloodborne pathogen standard explains OSHA's definition of respiratory protection. Under permissible practice OSHA states,

In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smoke, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures.°

The bloodborne pathogen standard "applies to all occupational exposure to blood and other potentially infectious materials... that may result from the performance of an employee's duties." The standard specifically defines bloodborne pathogens and other potentially infectious materials. Other relevant definitions in the standard include occupational exposure, engineering controls, and universal precautions. Scientists and physicians at NIOSH have concluded that plume contains blood, tissue, and body fluids that can contain bloodborne pathogens. Keeping all of these facts in mind, health care facilities still do not provide adequate protection for staff members. Ironically, hospital facilities are "No Smoking" facilities, yet they continue to allow smoke in the OR.

A Case Study

One of the biggest challenges as the laser endoscopic coordinator at Gwinnett Hospital System, Lawrenceville, Ga., was implementing a policy for proper surgical smoke evacuation and ensuring physicians' and OR staff members' compliance with the policy. Many surgeons did not believe the hazards were valid and felt that evacuation interfered with procedures while adding unnecessary costs for patients. Some staff members smoked, and the same denial associated with cigarette smoking was transferred to the risks related to surgical smoke. Other staff members saw evacuation as unnecessary, adding an extra piece of equipment to set up and make noise. I also had to convince administrators that they had a responsibility to their employees to provide safe practice within the OR setting.

Data Collection. To overcome these obstacles, I first provided information about the hazards of surgical smoke to the hospital safety officer. This included data according to the rules of continuous quality improvement to prove that surgical smoke was hazardous to employees' health. This was difficult to prove because the studies were subjective and no data quantified the direct correlation of disease due to smoke exposure. The data proved that the potential for transmission exists and that there are similarities between electrical surgical smoke and laser smoke. The safety officer called OSHA and relayed the data and information. Consequently, OSHA confirmed that respiratory protection should be available to OR staff members.

Let the Education Begin. The best way to reach physicians is to deliver the message via another physician. Douglas Ott, MD, who has researched surgical smoke and its effects on OR personnel, presented his findings to the Gwinnett physician staff. This gave the information more credibility, but it did not make them all believers. Some physicians still expressed skepticism regarding the pathology impact. In the end, physicians accepted the policies; however, they asked that evacuation costs not be passed on to patients and that staff members still made procedures the priority.

Product evaluation and training. An equipment and product evaluation process was put into place at Gwinnett. All types of companies who distributed smoke evacuation equipment came to the hospital and presented their products. Product selection was based on ▲ size (e.g., the smaller the better);
▲ effectiveness;
▲ noise production (e.g., the quieter the better);
▲ foot pedal activation (so that the device could be turned off when smoke was not being generated, further reducing noise);
▲ filter monitoring capabilities that indicate when the filter has met its potential and should be changed;
▲ fluid removal capabilities;
▲ filter and canister design that decreases staff members' chance of exposure to contaminants when the filter is discarded; and
▲ a single-use, 0.1 micron filter that would not compromise the flow rate of the wall suction.

With all this in mind, the evacuators and filters were chosen. The amount of equipment purchased was determined by the types and number of surgical procedures performed during the past year. This ensured appropriate equipment was available for all surgical cases. A mandatory program explaining the hazards of surgical smoke and the proper setup of equipment was presented to staff members.

Unexpected Problems. After product selection and training, policy implementation seemed to be going well. Unfortunately, this was not the case. Physicians complained that staff members were not paying attention to procedures and that the smoke evacuators were too loud. Physicians went so far as to say that the evacuators were not helping, only
Figure 1: Cumulative particle concentration for breast reduction, no smoke removal. Particle concentration climbs to and remains near one million particles per cubic foot within five minutes after electrocautery begins.

Figure 2: Cumulative particle concentration for breast reduction and implant removal/replacement, smoke removal system #1. Concentration falls on average to below 500,000 particles per cubic foot, but episodes of higher concentration still occur.

Figure 3: Cumulative particle concentration for breast reduction, with and without smoke removal system #2 (hand-held). The concentrations with this smoke removal system do not differ significantly from that of system #1.

Figure 4: Cumulative particle concentration for implant removal/replacement, with and without smoke removal system #2. The concentrations generated here do not differ significantly from those generated during breast reduction.

Figure 5 shows the cumulative particle concentration traces for two sequential breast reduction procedures superimposed, one during which smoke removal system #3 was used, and one during which system #4 was employed.

**Discussion**

Though breast reduction surgery is smoke intensive—particle concentrations near one million per cubic foot—our present study suggests that concentrations from other electrocautery procedures (e.g., breast implant removal and replacement) can rise to the same level, depending on the magnitude of cutting required, as shown in Figure 4.

Previous results' and Figure 2 suggest that smoke removal...
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