

Bovie Smoke

A Perilous Plume

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When analyzed, smoke from electrosurgical units, commonly known as Bovie smoke, is shown to be quite similar to that of other potentially pathogenic smoke, behaving as a carcinogen, a mutagen and an infectious vector. In addition, particulate matter in smoke is known to have health risks related to inducing inflammatory and allergic responses in susceptible people.

The fact that electrosurgical smoke is common and has been present in operating rooms for many years has led to a complacency regarding this smoke and its potential toxicity. A comparison of laser plume and electrosurgical smoke shows little difference in terms of the health risk, and in some respects the electrosurgical smoke poses a greater risk, particularly if these risks are quantified on a time-weighted basis that takes into account accumulation over long periods of exposure. For example, a study that directly compared electrosurgical smoke with laser plume and tobacco smoke showed that electrosurgical smoke is more toxic than laser plume or tobacco smoke (5). One gram of tissue was lasered with a carbon dioxide laser, and an identical gram of tissue was vaporized with electrosurgical current. A comparison of the emitted chemical byproducts to those present in average tobacco smoke demonstrated that the laser smoke generated from a gram of tissue was equivalent to smoking three unfiltered cigarettes, while the electrosurgical smoke was equivalent to smoking six unfiltered cigarettes.

This article details some of the known risks of exposure to Bovie smoke. As importantly, it presents best practices for avoiding Bovie smoke exposure to the greatest extent possible.

Electrosurgical units transmit a current from a dissecting or cutting surgical instrument to a dispersion electrode. The resistance to the flow of this current at the tissue interface generates heat, which causes coagulation of proteins that leads to hemostasis and vaporization of tissue by superheating intracellular water content. The result is disintegration of cell integrity and aerosolization of cellular debris. The destruction of biological tissue with heat results in the generation of smoke that is

composed of volatile organic compounds, inorganic compounds, and both inert and biologically active particulate matter such as viruses. The smoke generated by an electrosurgical unit is comparable to that generated by a laser, and the mechanism is fundamentally the same (3). Aerosols of biological tissue and smoke due to heat generated by friction also are generated by high-speed air drills.

The mutagenicity of electrocautery smoke has been evaluated by collecting smoke produced during reduction mammoplasty (6). The smoke was collected at locations between two-and-a-half and three feet above the operative field, typical of the exposure experienced by the operating team. The smoke was collected in filters and extracted for analysis. The extracts were tested with strains of *Salmonella typhimurium* in a standardized Ames test, which is a well-recognized technique for evaluating the mutagenicity of a substance. The results demonstrated that all of the smoke samples contained mutagens. The finding of mutagens is an important qualitative result because there is no established safe level of mutagens, and the likelihood of establishing safe levels is quite remote. Therefore, the implication is that the amount of smoke to which operating personnel are exposed should be as minimal as possible.

Volatile Organic Compounds

With regard to carcinogenicity, attention is typically focused on the volatile organic compounds and polycyclic aromatic compounds contained in the smoke. A health hazard evaluation report by the National Institute for Occupational Safety and Health, NIOSH, discussed the content of volatile organic compounds in surgical smoke (7). Volatile organic compounds are described as a class of molecules that have a sufficiently high vapor pressure to allow the compound to exist in a gaseous state at room temperature. Of the array of chemicals known to exist in biological tissue smoke, formaldehyde, acetaldehyde, and toluene were identified.

Formaldehyde concentrations were quite variable. They ranged as high as 0.021 parts per million, ppm, compared to a sample taken outside

the operating room door of 0.005 to 0.007 ppm. Formaldehyde is known to be an irritant at exposures of 1.0 ppm or greater in the general population, but symptoms of irritation occur earlier in persons with preexisting conditions such as allergies or respiratory disease. In addition, NIOSH identifies formaldehyde as a potential human carcinogen, and the Occupational Safety and Health Administration, OSHA, has identified a 0.75 ppm eight-hour time-weighted average as the upper limits of allowable worker exposure. The time-weighted average accounts for the elevation in the concentration of formaldehyde during exposure to surgical smoke over a period of time in a typical working day.

The report identified acetaldehyde concentrations that ranged from 0.001 ppm to 0.012 ppm, compared to a background of 0.002 ppm. Acetaldehyde is considered by the Environmental Protection Agency as a probable human carcinogen, and NIOSH recommends keeping exposure to acetaldehyde at the lowest feasible concentration. However, the OSHA guidelines for an eight-hour time-weighted exposure are much higher than those identified in this report at 200 ppm.

Toluene was identified in concentrations of 0.002 ppm to 0.015 ppm. Toluene is a known respiratory and eye irritant, and excessive inhalation exposure can lead to neurotoxicity. The symptoms of toluene exposure are not identified below 100 ppm in published studies.

The Particulars of Particulate Matter

Particulate matter is found in electrosurgical smoke, and the nonliving particulate matter is typically quantified as particles per cubic foot, ppcf. It has been noted that baseline measurements in an operating room are typically near 60,000 ppcf (4). With the use of electrosurgical tools that generate smoke, the typical rise in particulate

matter plateaus at approximately one million ppcf in five minutes. It takes approximately 20 minutes following cessation of generation of electrocautery smoke for the operating room ventilation system to return particulate concentrations to baseline level. Comparison of laser plume and electrosurgical smoke using a spectrophotometer has demonstrated that both types of smoke have a very similar particle content and size distribution.

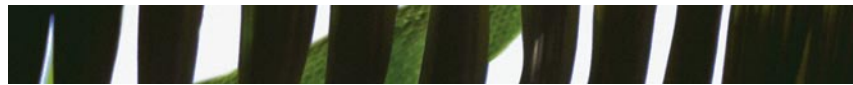
The smaller particulate matter is thought to be the most harmful in that it typically penetrates surgical masks and travels through the respiratory tree to the alveolar level. The particles typically are less than five microns in size, and more than 77 percent of particulate matter within surgical smoke is less than 1.1 μm in size. An experimental protocol using Sprague-Dawley rats exposed to electrocautery exhaust demonstrated lung parenchyma changes, including alveolar congestion, blood vessel hypertrophy of varying degrees, focal emphysematous changes, and muscular hypertrophy of blood vessels (10). A previous study demonstrated similar changes with carbon dioxide laser plume (2).

The particulate matter also includes living organisms, and both viable bacteria and viruses in electrosurgical smoke has been reported. Papillomavirus was identified in vapor from bovine warts treated with both laser-derived material and electrosurgical cautery (8). Of the two, more virus load was present in the laser-derived material. Despite this provocative finding, the size of these particles is such that they are easily filtered out by a surgical mask and that there appears to be a low likelihood of transmission of the papillomavirus through its presence in electrosurgical smoke. Surgical smoke has been identified to carry viable bacteria that have been cultured from surgical smoke, including *Bacillus subtilis* and *Staphylococcus aureus*. In addition, mycobacteria

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Bovie smoke behaves as a carcinogen, a mutagen and an infectious vector and can induce inflammatory and allergic responses in some people.



Evacuation of the Bovie smoke near the source has the greatest likelihood of preventing exposure and any health consequences associated with it.

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have been isolated from smoke, including *Mycobacterium tuberculosis* (9).

However, the presence of carcinogenic and mutagenic chemicals as well as inert and biologically active particulate matter represents a health hazard that varies with the susceptibility of the exposed individual. The presence of hypersensitivities, allergies, immunocompromised states, and/or a combination of surgical toxic exposures with other toxic environmental exposures such as smoking may change the risk profile on a case-by-case basis. Given the complexity of the variables involved, individual risk stratification cannot be established in a rigorous scientific fashion. The hazards of electro-surgical smoke are for the most part potential hazards without a large epidemiological database demonstrating their harmfulness to humans. In the presence of a scientifically verifiable hazard and the absence of definitive epidemiologic proof of health consequences, the most prudent course of action is to minimize exposure, which has virtually no downside risk.

Evacuators and Masks

There is almost uniform agreement among authors in this field that evacuation of the smoke near the source has the greatest likelihood of preventing exposure and any health consequences associated with it. The NIOSH recommendations suggest a smoke evacuator system that can pull approximately 50 cubic feet per minute with a capture velocity of 100 to 150 feet per minute at the inlet nozzle (1). Filters are necessary to capture the contents of the smoke and must be replaced regularly. Used filters are considered biohazardous wastes that require proper

disposal. The regulations further suggest that a smoke evacuator nozzle be kept within two inches of the surgical site to maximize effective capturing of airborne contaminants. The use of routine suction designed for elimination of liquids from the surgical field is not adequate to evacuate electro-surgical smoke and eliminate the health hazards associated with it.

The other common practice is the use of a surgical mask. It is true that surgical masks cannot eliminate the very fine particles that are associated with respiratory inhalation, and even high-efficiency

masks will become saturated at a certain point, thus allowing the air to flow around the mask rather than through it. Nonetheless, the masks are efficient in eliminating larger particle sizes, including viruses. **NS**

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