Hazards of vaporized tissue

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plume

While the medical use of cautery for the treatment of hemorrhage and lesions has been documented since 3000 BCE, it was not until the early 1800s when newly discovered electricity was used to heat a probe for cauterization. In 1936 the first practical electrosurgical unit (ESU) was designed by WT Bovie and used by the famed neurosurgeon Harvey Cushing. Since the ESU has become recognized as an invaluable tool in medicine and widely accepted, its use has been estimated in 90 percent of the 24,000,000 cases performed each year. For the surgical team, the inhalation of vaporized tissue plume is routine and has been accepted as part of the working environment. Occasional upper respiratory tract and ocular irritation is expected. Additionally, the view of the surgical field may be temporarily obstructed by the plume, causing minor delays.[1,7]

It was not until laser surgery became popular in the 1980s that concerns grew about the laser plume's content. Coincidentally, this was about the same time the true hazards of tobacco smoke became evident to the general public. Research studies were conducted in the early 1980s to determine the content of plume, as well as the potential hazard of exposure to the pungent white/gray billow that emanates from both the laser and the ESU as it cuts and cauterizes tissue. Researchers were able to identify chemical byproducts contained in the vaporized tissue plume and noted that particle size in the plume ranged from 0.1 to 0.8 microns. (Standard surgical masks are capable of 5.0 micron particle diameter filtration.)[7] Research also demonstrated that exposure to laser plume caused pathological changes in the lungs of rats and that a carbon dioxide laser could vaporize intact DNA from the human papilloma virus (HPV).[7]

An increase in the number of procedures that can be performed endoscopically prompted additional research in the 1990s. This research demonstrated that:

- plume within the abdominal cavity reduced the oxygen-carrying capacity of the blood due to an increase in methemoglobin.
- HIV DNA was detected in laser plume in culture on the 14th day.

As a result of these findings, the National Institution for Occupational Safety and Health (NIOSH) issued a hazard control statement that calls for evacuation of plume generated by electrosurgical units and lasers.[7]

Vaporized tissue plume

Vaporized tissue plume is the term commonly used to describe the smoke generated when tissue (including bone) is thermally destroyed and vaporized through the use of the ESU or the laser. However, when discussing plume, it is important to include the smoke and aerosol that is formed with the use of power instrumentation, such as saws, drills, and reamers, and devices that produce pulsatile lavage. Even if proper cooling techniques are used, power instrumentation can produce a vaporized tissue plume, and aerosol formation is likely with pulsatile lavage devices. Although, aerosols may not contain the byproducts associated with smoke, they must be considered airborne contaminants and treated accordingly.

Whatever the original source, all vaporized tissue plume is similar in content.[2] The plume has been shown to contain more than 600 components (Table 1), some of which are known to be toxic, mutagenic, and carcinogenic. Among the known hazards is benzene, which is documented as being a trigger for leukemia.[7] Precautions are mandated in OSHA's booklet, "Health Hazards of Benzene." For more information about the other hazardous components of plume, refer to www.osha-scl.gov or the hospital's Material Safety Data Sheets (MSDS).

One study comparing cigarette smoke to laser-generated smoke, demonstrated that 1 gram of tissue cut with the carbon dioxide laser was found to have the same harmful potential as smoking three unfiltered cigarettes.[7]

More recent studies have been directed toward the possibility of active/viable microbial cells within the plume. Transmission by inhalation has been reported, and in one case, a 44-year-old laser surgeon developed laryngeal papillomatosis. Biopsies revealed HPV DNA types consistent with the anogenital condylomas lased from his patients. Another report involved a patient who underwent laparoscopic resection of an intraabdominal tumor. The patient later developed trocar site metastasis, suggesting that active cancer cells in the smoke may have attached to the trocar, which were transferred to the tissue as the trocars were

Table 1 Chemical and biological byproducts found in vaporized tissue plume [2,4,5,7,8]

Acetonitrile	Ethylene	Propylene
Acetylene	Formaldehyde	Pyridine
Acrolein	Free radicals	Pyrrole
Acrylonitrile	Gasses	Styrene
Alkyl benzenes	Hydrogen cyanide	Toluene
Benzene	Isobuteine	Trace toxic gasses
Butadiene	Methane	Viral fragments
Butene	Microbial cellular DNA constituents	Water vapor
Carbon monoxide	Organic vapors	Xylene
Carbonized cell fragments	Particulate matter	
Creosols	Phenol	
Ethane	Polycyclic aromatic hydrocarbons	
Ethene	Propene	

FIGURE 1

Plume-away devices attach to the patient's skin or the drapes.

removed. Also under investigation is the potential build up of carbon monoxide within the patient's abdomen and its potential to reach a toxic level.

As studies continue to pinpoint potential vaporized tissue plume hazards, steps must be taken to protect the surgical team members (including auxiliary personnel) and the patient from exposure. Patients undergoing laparoscopic procedures and receiving general anesthesia alternatives are at highest risk.

Recommended clinical practice guidelines

Recommended clinical practice guidelines, presented in Table 2, are a combination of recommendations from the American Society for Laser Medicine & Surgery, the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety & Health Administration (OSHA—US Department of Labor), and the Ontario Ministry of Labour (Canadian Centre for Occupational Health and Safety).

Please note that these are recommendations, not requirements. Currently, there are no standards specific to vaporized tissue plume; however, compliance with specific standards is applied to certain situations.[5] Examples include:

- Standard Precautions are used in all patient-care situations in which blood, any body

Table 2 Clinical practice guidelines[1,4,5,6]

1. **Vaporized tissue plume (from any source) should be considered potentially hazardous for two reasons:**
   - A. *Presence of particulate matter*
   - B. *Presence of infective agents*
2. **Vaporized tissue plume should be collected by an appropriate mechanical evacuation system at all times. Ideally, the evacuation system will:**
   - A. *Have a high flow volume.*
   - B. *Be vented outdoors.*
   - C. *Contain an appropriate filter (HEPA, high-efficiency particulate air, or ULPA, ultra-low penetration air, used with charcoal) that has the ability to detect overloading and is subject to frequent filter changes.*
   - D. *Allow placement of the evacuator nozzle/tip as close to the point of origin of the vaporized tissue plume (2-5 cm) as possible.*
   - E. *Treat disposable components as biohazardous material, as needed.*
   - F. *Have non-disposable components sterilized prior to reuse, as needed.*
   - G. *Be maintained according to the manufacturers recommendations.*
3. **Personal protective equipment is required in all situations that vaporized tissue plume is generated.**
   - A. *Appropriate clothing—fluid-resistant or fluid-proof long-sleeve apron or surgical gown.*
   - B. *Eye protection—sufficient to protect from splatter.*
   - C. *Mask—effective filtration or respirator.*
   - D. *Gloves—latex preferred or suitable substitute.*
4. **Smoke evacuation should be carried out independently of fluid aspiration**

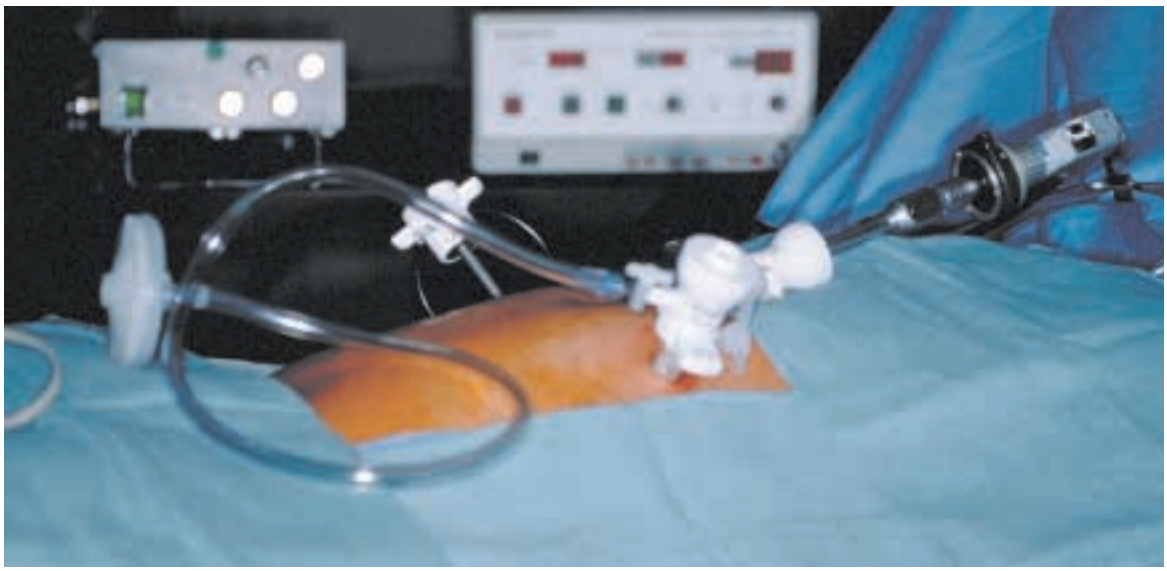

FIGURE 2

The Plume-Away Lap SES attaches to the outflow port during laparoscopy

fluid, secretion, or excretion (with the exception of sweat), non-intact skin, and mucous membranes may be encountered.

- General Duty Clause 5(a)1 OHS Act of 1970 states the duties of the employer and responsibilities of the employee in reference to workplace hazards.
- OHSA Standard 1910.134(a)(1) Respiratory Protection's primary objective is to control occupational diseases caused by breathing air contaminated with harmful substances. This is to be accomplished through accepted engineering controls if feasible or through the use of appropriate respirators. (Note: surgical masks used to prevent contamination of the patient are not certified for respiratory protection of medical employees.)
- OSHA Standard 1910.1030(d)(3)(i) Bloodborne Pathogens states that the employer must supply appropriate personal protective equipment, such as gloves, gowns, masks, and eye protection. This standard would apply if such items become contaminated with viable blood-borne pathogens from vaporized tissue plume.

Methods for removal

Two main methods are used to remove airborne contaminants from the operating room.

1. Room-air exchange systems, such as laminar flow, are not sufficient to capture vaporized tissue plume at its point of origin. The surgical team and patient have already been exposed to the contaminants prior to their removal from the operating room.
2. Local exhaust ventilation offers several methods to capture vaporized tissue plume at its point of origin. Ideally, the local exhaust-ventilation system is composed of an inlet nozzle or tip, hose, filter, and suction unit.
   A. Hand-held wand attached to a suction device. This technology has been available for more than a decade and is effective only when the surgical first assistant is able to hold the device in close proximity to the plume's point of origin.

B. An adhesive device attached to the patient's skin or the drapes (Figure 1 Plume-Away). This new technology does not require any additional intraoperative handling once positioned and allows for capture, filtration and deodorization of vaporized tissue plume.

C. A device that is attached to the outflow port during laparoscopy (Figure 2 Plume-Away Lap SES). This is another new technology that does not require additional intraoperative handling once positioned. It also allows for capture, filtration and deodorization of vaporized tissue plume.

The most effective protection against vaporized tissue plume at this time is a high-flow smoke evacuator that captures smoke at its point of origin. Currently in use are several systems such as the Stackhouse high-flow evacuator, the Sun Medical SFE-200, and the JLJ Medical Devices International, LLC, Plume-Away.

As concern grows over vaporized tissue plume generated during surgery, additional research is necessary, current methods for evacuation must be evaluated, and new evacuation systems must be developed to protect the patient and surgical team from exposure.

About the author

Kevin Gracie is a self employed CST/CFA and has provided surgical assistant services to 11 hospitals and clinics in the Minneapolis/St Paul metropolitan area since 1994. Previously, he was a surgical assistant for 15 years at the Institute for Low Back Care.

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Photos courtesy of JLJ Medical Devices International, LLC, Minneapolis, Minnesota.