The Hazards of Surgical Smoke
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Technical Data Monograph
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Section 1

Introduction

Surgical smoke has become a major concern to health care providers in today’s surgical environments. This monograph is a compilation of research studies, statements, and recommendations showing that every effort must be made to adequately remove surgical smoke to minimize its hazards. STERIS Corporation is committed to helping achieve positive patient outcomes and committed to helping create safer working environments for healthcare professionals.

Section 2

Electrosurgery vs. Laser Plume

The number of surgical procedures continues to grow each year as surgery is performed in hospital operating rooms, ambulatory surgery centers, clinics, and even physician offices. Approximately 90% of endoscopic and open procedures generate some level of surgical smoke or plume. (Ulmer B, 1998)

During operative procedures, “hot” tools, such as lasers or electrosurgical units (ESU’s), are used to vaporize, coagulate, and ablate tissue. Target cells are heated to the point of boiling with these tools causing cellular membranes to rupture and cellular contents to be spewn into the air creating surgical smoke. Estimations note that approximately 350,000 healthcare workers are exposed to surgical smoke each year creating a hazardous work environment. (Ulmer B, 1998)

Electrosurgery has been used since the 1920's while laser technology was accepted into the surgical arena during the 1980's. Surgical smoke generated by ESU’s has haunted surgical suites for years without any recognition of the inhalation hazard. When laser technology became popular, the dangers of surgical smoke finally gained the credit and visibility it deserved. Classes and conferences about laser biophysics, safety, and clinical techniques almost always include the hazards of laser smoke; so whenever a laser is used, a smoke evacuation method also is employed. But when an ESU is used, smoke evacuation is often overlooked even though studies have shown that the contents of laser and ESU plume are very similar and hazardous.

In 1989, Dr. Tomita and other Japanese researchers compared cigarette smoke to laser and electrosurgery smoke (Tomita et al., 1989). They lasered one gram of tissue with a CO₂ laser, collected the plume, and found that this plume had the same hazard potential as smoking three unfiltered cigarettes. When the electrosurgery unit was used, the plume was equivalent to smoking six unfiltered cigarettes. Therefore, the plume produced during electrosurgical procedures was proven to be twice as harmful as laser plume.
Surgical smoke can cause burning, watery eyes, nausea, respiratory problems, and maybe even pathogenic contamination and regrowth. (Ball K, 2004) Because of these unwanted hazards and potential complications, complete evacuation of surgical smoke is necessary. Even though the results of many research studies have repeatedly proven the hazards of plume, smoke evacuation still has not become a standard practice in many surgical environments. The lack of appropriate smoke evacuation devices and physician and surgical team indifference are just two reasons that surgical smoke is still a problem in surgery today.

Research has conclusively shown that surgical smoke is hazardous to the surgical team members who are exposed to it day after day. There are three main reasons that cause plume to become a major source of concern and problem:

- Odor
- Size of the particulate matter
- Viability of the particulate matter

**ODOR**

The noxious odor from surgical smoke is caused by the chemical byproducts and toxins that are emitted when a “hot” tool is used to vaporize, cut, ablate, excise, or coagulate tissue. The following toxic chemical byproducts have been identified in surgical smoke resulting from tissue pyrolysis: (Hoglan M, 1995 and Ott D, 1993)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrolein</td>
<td>Free radicals</td>
</tr>
<tr>
<td>Acetonitrile</td>
<td>Hydrogen cyanide</td>
</tr>
<tr>
<td>Acrylonitrile</td>
<td>Isobutene</td>
</tr>
<tr>
<td>Acetylene</td>
<td>Methane</td>
</tr>
<tr>
<td>Alkyl benzenes</td>
<td>Phenol</td>
</tr>
<tr>
<td>Benzene</td>
<td>Polycyclic aromatic hydrocarbons</td>
</tr>
<tr>
<td>Butadiene</td>
<td>Propene</td>
</tr>
<tr>
<td>Butene</td>
<td>Propylene</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Pyridene</td>
</tr>
<tr>
<td>Creosols</td>
<td>Pyrrole</td>
</tr>
<tr>
<td>Ethane</td>
<td>Styrene</td>
</tr>
<tr>
<td>Ethylene</td>
<td>Toluene</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Xylene</td>
</tr>
</tbody>
</table>

Some estimate that there may be over 600 additional compounds within surgical smoke that have yet to be identified. But some of these toxins, including polycyclic aromatic hydrocarbons, benzene, toluene, formaldehyde, and acrolein, are gases that are already known carcinogens and with repeated exposures can become hazardous when inhaled.
SIZE OF THE PARTICULATE MATTER

The following studies indicate how particulates in surgical smoke are smaller than what regular surgical masks filter, and that these surgical smoke particles can cause respiratory problems.

1981 (Mihashi, Ueda, Hirano, Tomita, & Hirohata)
When a CO₂ laser was used to vaporize tissue, the surgical smoke produced was 52 times greater than that allowed by the government's environmental standards. Further results noted that approximately 77% of the particulate matter in the plume was less than 1.1 microns in size. Since a regular surgical mask filters particulate matter that is 5 microns in size, most of the plume can easily pass through a mask and be deposited in the alveoli of lungs when inhaled causing chronic irritation, bronchitis, or emphysema-like conditions.

1988 (Baggish, Baltogannis, & Sze)
A study was conducted to compare the effects of laser smoke on rat lungs. Three groups of rats breathed in large amounts of plume that were created by impacting pigskin with a CO₂ laser beam for different time durations. All of these rats developed hypoxia and pulmonary congestion with bronchial hyperplasia and hypertrophy. Another group of rats was subjected to plume that was filtered down to 0.1 microns in size. This group developed no lesions and remained identical to the control rats. Supporting studies conducted by Dr. Barry Wenig found that the results regarding the harmful effects of CO₂ laser smoke also applied to the use of the electrosurgery unit and the Nd:YAG laser. (Stackhouse Inc., 1992)

1991 (Helnsohn et al.) and 1992 (Smith et al.)
Using different techniques, both of these research studies noted that electrosurgery produced an aerosol with particulate matter that was less than 5 microns in size.

VIABILITY OF THE PARTICULATE MATTER

The transmission of viable bacteria and viruses through inhalation of surgical smoke has not yet been conclusively proven. However, concerns over viability continue to increase. The following research studies support smoke particulate viability and the potential for transmission:

1985 (Mullarky, Norris, & Goldberg)
Researchers discovered that when bacteria was placed on pigskin and was then impacted by the CO₂ laser, viable bacteria could be found in the plume.

1986 (Walker, Matthews, & Newsom)
This study noted that cellular clumps and erythrocytes can be found in laser plume. Also the study proved that viable cells could probably survive if the laser were operated at lower power settings.

1987 (Byrne, Sisson, Oliver, & Ingham)
Bacteria were successfully cultured from laser plume indicating that plume cell viability is determined by the power density of the laser beam on the tissue.
1988 (Garden et al.)
Dr. Jerome Garden and his associates were able to extract intact viral DNA from the plume emitted when a CO\textsubscript{2} laser was used to vaporize bovine fibropapillomavirus. The material was then reinoculated back into the host (cattle) and the same papilloma viral lesions grew. This study noted that viral DNA can cause viral growth in the host if inoculated. Further studies need to be conducted to note if viral transmission and regrowth are possible through inhalation.

1988 (Lobraico, Schifano, & Brader)
A retrospective survey noted there were 26 incidences of transmitted verrucous lesions to health care providers (4 being proven by biopsy) from infected patients being treated surgically. Conclusions made from the survey indicated that strict adherence to wearing gloves and masks, plus the elimination of plume through adequate smoke evacuation methods are absolutely mandatory.

1989 (Sawchuk, Weber, Lowy, & Dzubow)
Sawchuk and his team used a CO\textsubscript{2} laser and an electrosurgery unit to vaporize warts caused by papillomavirus. Results from this study noted that viral DNA was present in the vapors generated from treatment with a laser or electrosurgery but did not determine whether the papillomavirus material in the plume was infectious.

1991 (Baggish, Poiesz, Joret, Williamson, & Refai)
This research detected human immunodeficiency virus DNA in laser plume. There was no sustained viability but there was positive tissue culture in the tubing of the evacuator.

1991 (Hallmo, & Naess)
A case was reported that a 44 year old laser surgeon in Norway developed laryngeal papillomatosis. Testing noted that his tumor biopsy revealed human papillomavirus DNA types consistent with the anogenital condyloma that were being lased on his patients. Therefore, the possibility for inhalation spread of viable particulate matter in surgical smoke became even more evident.

1992 (Gatti, Bryant, Noone, & Murphy)
Multiple air samples were taken during reduction mammoplasties to determine the mutagenicity of the smoke produced by electrosurgery. Results noted that the electrosurgery smoke particles were found to be mutagenic. The researchers concluded that the surgical team should attempt to minimize exposure to surgical smoke.

**PLUME DURING ENDOSCOPY**

Plume left in a body cavity during endoscopy can be absorbed by the body; therefore, it must be evacuated adequately. A low-pressure suction valve positioned along the suction line or special low-pressure smoke evacuators are available to gently evacuate surgical plume during endoscopy. The following research study supports the need to evacuate surgical smoke during laparoscopic procedures.

1993 (Ott)
Research showed that when surgical plume is not evacuated during a laparoscopic procedure, an increase in methemoglobin and carboxyhemoglobin occurs while oxygenation of the tissue decreases. The patient usually presents with nausea and vomiting in response to this problem.
The hazards of surgical smoke continue to be recognized as the results of more research studies are published. Professional organizations along with agencies and research groups have even developed guidelines and statements regarding these hazards. These recommendations should be followed closely by healthcare professionals to minimize the hazards of surgical smoke. Some of these recommendations and statements that are based on conclusive research are listed below:


“Electrosurgical devices and instrumentation are often used both separately and simultaneously with healthcare laser systems. These devices have been found to produce the same type of airborne contaminants as produced by laser-tissue interaction, and these contaminants should be evacuated from the surgical site.”

“In operations that use Class 4 lasers, the vaporization of target tissue produces laser generated airborne contaminants (LGAC).... Analysis of the LGAC has shown the presence of gaseous toxic compounds, bioaerosols, dead and live cellular matter, and viruses.... Laser users need to be aware of the potential for such products (LGAC) during any medical/surgical procedures and utilize control measures such as universal (standard) precautions that are covered by the Blood Borne Pathogen Standard (CFR 1910-1030).”

**National Institute of Occupational Safety and Health (NIOSH) and the Centers for Disease Control and Prevention (CDC), “Control of Smoke from Laser/Electric Surgical Procedures,”** 1996:

(http://www.cdc.gov/niosh/hc11.html)

“During surgical procedures using a laser or electrosurgical unit, the thermal destruction of tissue creates a smoke byproduct. Research studies have confirmed that this smoke plume can contain toxic gases and vapors such as benzene, hydrogen cyanide, and formaldehyde, bioaerosols, dead and live cellular material (including blood fragments), and viruses. At high concentrations the smoke causes ocular and upper respiratory tract irritation in healthcare personnel, and creates visual problems for the surgeon. The smoke has unpleasant odors and has been shown to have mutagenic potential.”


“Personnel working in the laser environment should avoid exposure to smoke plume generated during laser surgery... To reduce smoke plume inhalation, local exhaust ventilation controls should be implemented. These controls include, but may not be limited to wall suction units with in-line filters, and smoke evacuation units... Personnel should wear high-filtration surgical masks... during laser procedures that generate smoke plume... The evacuator collection apparatus should be placed as close as possible to the laser site... Laser gas airborne contaminants produced during laser procedures have been analyzed and are shown to contain gaseous toxic compounds, bioaerosols, and dead and living cell material... and have demonstrated mutagenic and carcinogenic potential.”

**Association of periOperative Registered Nurses (AORN): “Recommended practices for electrosurgery,”** (2004):

“Exposure to smoke plume generated during electrosurgery should be minimized... The smoke has been found to contain toxic gases and vapors; bioaerosols, including blood fragments; and viruses. In high concentrations, the smoke causes ocular and upper respiratory tract irritation in health care personnel.”

**Association of periOperative Registered Nurses (OARN): “Recommended practices for endoscopic minimally invasive surgery,”** 2004:

“Smoke and laser plume should be evacuated throughout the procedure with appropriate smoke evacuation equipment. The release of gas, electrosurgical smoke, and laser plume during endoscopic surgery may expose surgical team members to blood products, fluid, and cellular debris. A smoke evacuation system provides protection and reduces the risk of exposure to potentially infectious or toxic agents.”
American Society for Laser Medicine and Surgery (ASLMS), Statement, 1995:

“All medical personnel should consider the plume to be potentially hazardous both in terms of the particulate matter and infectivity.... Evacuator suction systems should be used at all times to collect the plume.... These guidelines are based on the assumption of the presence of a real hazard to those individuals who are exposed to the plume.”

Occupational Safety and Health Administration (OSHA):

OSHA recommends that smoke evacuation systems be used to reduce potential acute and chronic health risks to patients and personnel. OSHA has not published a specific official statement on the hazards of surgical smoke, but believes that the OSHA “general duty clause” (stating that the workplace environment should be free from hazards) indirectly address the need to eliminate inhalation hazards such as surgical smoke.
Section 6  Recommendations & Guidelines


OTHER READINGS

AORN. (1997) Surgical Services Management 3(3), Issue on Smoke Hazards.


