Surgical smoke in dental practice: a potential biohazard

Akhil Kannyadath Padmanabhan PG, Shobith Mampuzha PG, Prabhuji MLV HOD, Ashwin PS PG

ABSTRACT

BACKGROUND: With the advent of novel devices in surgery such as LASER and Electro surgery, surgical procedures in medicine and dentistry have become simpler. These devices offer the potential to reduce the intraoperative and postoperative bleeding, optimizes the healing and may reduce the healing time as well as the surgical complexity of the procedure. However, these devices are found to produce hazardous smoke during the procedure which is referred to as surgical smoke.

OBJECTIVES: The objective of this literature review is to identify the potential hazards of surgical smoke in dentistry and also to explain in brief about the methods of reducing smoke production in the operatory and thus reducing the health hazards it may cause.

METHODS: Articles pertaining to the key words “Surgical smoke”, “surgical plume”, “electrocautery smoke” and “laser smoke” were searched in MEDLINE database of references and abstracts on life sciences and biomedical topics. 37 articles (including reviews) were collected and analyzed for relevant information, segregated and the inferences were gathered into a structured literature review.

RESULTS: The available evidences on surgical smoke in the medical and dental literature showed that surgical smoke poses a definite threat to the health of the operator and the staff in the operating room. The electrocautery smoke seemed to produce more harmful emissions compared to the laser plumes.

CONCLUSION: It can be concluded that dentists and the assisting staff should be educated about the potential risks of surgical smoke. The operating room should be equipped with proper evacuation system. Usage of respirators should be made mandatory so that both the patient as well as the operator should be at minimal risk from the emissions that are released during any procedures.

Key Words: Surgical smoke; Health hazard; Technology

INTRODUCTION

Surgical smoke, is not a novel issue in medical practice (1). Advancements in the technologies have led to the machineries that hazardous sources of air contaminants in the perioperative environment (1,2). Additionally, the awareness of this problem among the medical fraternity is less pronounced (3). Furthermore, there have been challenges in understanding the potential hazards associated with surgical smoke due to the gaps in the line of the literature. Surgical smoke can be generated by

- Thermal, ultrasonic, and laser scalpels used in cellular ablation and various cosmetic surgeries (1)
- Electrocautery and diathermy units used in surgeries (2)
- High-speed electrical devices, often used in plastic and orthotic surgery (1,3)

HOW SURGICAL SMOKE IS PRODUCED?

Surgical smoke can be produced by any energy-generating device. The most common devices are electrocautery, electrosurgical units (ESU) and ultrasonic devices, LASER devices and powered instruments such as bone saws and drills. When the energy generating devices are used on tissues, it increases the inter and intra cellular temperature (100° Celsius (212° Fahrenheit) or higher) which produces surgical smoke at 100° Celsius.

The incidences of using such devices in dental practice is significantly high which puts majority of the dentists and the health care workers associated with the operating room at an increased risk of developing health hazards due to prolonged exposure to such emissions.

Harshful substances found in surgical smoke include

- Viable strains of bacteria such as Staphylococcus aureus, Corynebacterium and Neisseria (2)
- Infectious aerosols such as Mycobacterium tuberculosis (TB) (4)
- Transmittable cells of Human Papilloma Virus (HPV) Hepatitis B (HBV) (5)
- Toxic gaseous substances such as, benzene, hydrogen cyanide, formaldehyde, methane and carbon monoxide (6)

OCCUPATIONAL SAFETYSSTATEMENTS BY NATIONAL AND INTERNATIONAL AUTHORITIES

The National Institute for Occupational Safety and Health (NIOSH) published and distributed a Health Hazard Evaluation Report in 1985 which led to the official recognition of “Surgical smoke” as a potential health hazard (7). NIOSH, a department of the Centers for Disease Control and Prevention (CDC) stated that there is a “potential hazard from exposure to smoke generated by electrocautery” (7). Ever since this report had been published, efforts have been made to emphasize the risks of surgical smoke and also the sources of plumes which is now also referred to as aerosols, cautery smoke, diathermy plumes, plumes or smoke plumes (8).

ELECTROCAUTERY

The chemical makeup and biological properties of electrocautery smoke have been studied in an effort to define and quantitate harmful substances present within the smoke. Numerous chemicals have been identified in surgical smoke, some of which are greatly hazardous and present in higher than negligible quantities. Chemicals that dominate in quantity in electrocautery smoke are hydrocarbons, nitriles, fatty acids, and phenols (9). Among them, Carbon Monoxide (CO) and acrylonitrile are of greater significance. There are other chemicals that are present in trace amounts which are also of significance which includes hydrogen cyanide, formaldehyde, and benzene. Carbon monoxide generation is of greater concern in laparoscopic procedures in general surgical procedures in which smoke is trapped and concentrated in the body cavities. According to the Occupational Safety and Health Administration (OSHA) the upper limit of ambient exposure to these substances is set at 2 ppm. Exposure levels of operating room staff have been demonstrated to be 1.0
The patient-care environments wherever surgical and invasive procedures are undertaken are bound to be exposed to surgical smoke (Figure 1). Since three decades, air quality of operating rooms is a cause of concern. Among the healthcare professionals, surgical smoke is a source of chronic irritation leading to health issues like respiratory illness, regular headaches, nausea, mucous membrane irritations and skin irritations. It can also be a cause for high rate of absence for work too.

Alp et al. (33) listed the potential risks associated with the exposure to surgical smoke for both patient and the health care professionals (Table 2). From the evidences, it is clear that surgical smoke poses a potential threat to the patient and the operating staff in the same environment alike. This fact is often ignored in both medical and dental settings.

![Figure 1](image)

**Chemicals present in surgical smoke and their health effects (34)**

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Health hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>Eye, respiratory irritant and skin effects. Clinical exposure to vapors also include erythema, coughing, pulmonary edema, narcosis. Teratogenic. Irritation can be expected after an exposure of 50 ppm for 15 minutes. Facilitates intake of other contaminants in the atmosphere by bronchial epithelium.</td>
</tr>
<tr>
<td>Benzene</td>
<td>Eye, skin, upper respiratory tract irritant. May increase blood clotting time and cause liver and kidney damage.</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Nose irritant, throat asphyxiant. Has caused liver and kidney damage in animal models.</td>
</tr>
<tr>
<td>Xylene</td>
<td>Headache, weakness, appetite loss, and fatigue. May cause bone marrow damage, injury to blood-forming tissue from chronic low-level exposure. The threshold value limit of parts per million inhaled intermittently over one year may alter nutritional status and gross metabolism.</td>
</tr>
</tbody>
</table>

**Cells/Cellular Substances**

The presence of viable cells in surgical smoke is controversial. This issue is of concern because of the potential for viable aerosolized cancer cells to seed distant sites such as trocar incisions leading to port-site metastases through a method known as the chimney effect. Although some studies have failed to show the presence of aerosolized cells in the peritoneal cavity during routine laparoscopic surgery (27), other studies reported the presence of cell-sized fragments (28), morphologically intact but nonviable cells (29), and surgical smoke with viable cells (30,31). A 1999 study in which a more sensitive method of cell viability detection was used, a tetrazolium mitochondrial viability assay instead of the trypan blue assay used in previous studies definitively demonstrated viable cells in laser and electrocautery smoke (32). The significance of the presence of these cells is not known. The presence of viable cells in the plume generated by the ultrasonic (harmonics) scalpel has not been formally investigated.

**Health Disorders Associated with Exposure to Surgical Smoke (Table 1)**

Occupational safety is of utmost importance in any work environment.

- Acetaldehyde: Osha pel: 0.25 mg/m$^3$, niosh rel: 10 ppm
- Benzene: Osha pel: 1 ppm (0.25 mg/m$^3$), niosh rel: 5 mg/m$^3$
- Xylene: Osha pel: 100 ppm; Acgh lv: 100 ppm
- Formaldehyde: Osha pel: 0.75 ppm (2.5 mg/m$^3$)
- Acetone: Osha pel: 200 parts per million (ppm) acgh tvl: 25 ppm
- Acrolein: Osha pel: 0.1 ppm (0.25 mg/m$^3$), niosh rel: 5 mg/m$^3$
- Acetonitrile: Osha pel: 40 ppm; Acgh lv: 40 ppm
- Benzene: Osha pel: 1 ppm (3 mg/m$^3$)
- Acgh lv: 10 ppm (32 mg/m$^3$), niosh rel: 0.1 mg/m$^3$
- Polyaromatic hydrocarbons (naphthalene): Osha pel: 10 ppm (naphthalene); Acgh lv: 15 ppm

**Table 1**

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Health hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>Eye, respiratory irritant and skin effects. Clinical exposure to vapors also include erythema, coughing, pulmonary edema, narcosis. Teratogenic. Irritation can be expected after an exposure of 50 ppm for 15 minutes. Facilitates intake of other contaminants in the atmosphere by bronchial epithelium.</td>
</tr>
<tr>
<td>Benzene</td>
<td>Eye, skin, upper respiratory tract irritant. May increase blood clotting time and cause liver and kidney damage.</td>
</tr>
<tr>
<td>Xylene</td>
<td>Nose irritant, throat asphyxiant. Has caused liver and kidney damage in animal models.</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Headache, weakness, appetite loss, and fatigue. May cause bone marrow damage, injury to blood-forming tissue from chronic low-level exposure. The threshold value limit of parts per million inhaled intermittently over one year may alter nutritional status and gross metabolism.</td>
</tr>
<tr>
<td>Acetone</td>
<td>Well absorbed via respiratory tract. Respiratory tract irritation begins at 200 ppm. Chronic exposure associated with reversible changes in red and white blood cell counts and increases in platelet counts.</td>
</tr>
<tr>
<td>Acrolein</td>
<td>Absorbed via respiratory tract. Ocular, respiratory irritant. Wide range of sensitivitiy. Effects noted in very low doses. Exposure likely occurs via particle inhalation. Styrene and acrolein may increase inhalation effect.</td>
</tr>
</tbody>
</table>

**Cells/Cellular Substances**

The presence of viable cells in surgical smoke is controversial. This issue is of concern because of the potential for viable aerosolized cancer cells to seed distant sites such as trocar incisions leading to port-site metastases through a method known as the chimney effect. Although some studies have failed to show the presence of aerosolized cells in the peritoneal cavity during routine laparoscopic surgery (27), other studies reported the presence of cell-sized fragments (28), morphologically intact but nonviable cells (29), and surgical smoke with viable cells (30,31). A 1999 study in which a more sensitive method of cell viability detection was used, a tetrazolium mitochondrial viability assay instead of the trypan blue assay used in previous studies definitively demonstrated viable cells in laser and electrocautery smoke (32). The significance of the presence of these cells is not known. The presence of viable cells in the plume generated by the ultrasonic (harmonics) scalpel has not been formally investigated.

**Health Disorders Associated with Exposure to Surgical Smoke (Table 1)**

Occupational safety is of utmost importance in any work environment.
Surgical smoke in dental practice: a potential biohazard

MANAGING SURGICAL SMOKE IN THE OPERATING ROOM

With the advancement and evolving technology of tissue dissection and bleeding control, surgical smoke is relatively a newer occupational hazard. Surgical smoke, plumes and aerosols produced by instruments used to dissect tissue and provide haemostasis make the patients and healthcare professionals exposed to potential hazard. Minimizing the production of surgical smoke, increasing the efficacy of the evacuation of smoke, and preventing inhalation of smoke by use of effective masks are some methods to prevent exposure. As surgical smoke puts the health of both the patient as well as the operator at risk, a well-planned and designed evacuation system is necessary. Additionally, Smoke evacuators are in practice, they are devices that capture and filter the plume generated during electrosurgical procedures or laser procedures, thereby maintaining a safe environment for the surgical team and the patient (Figure 2). A smoke evacuation system should be appropriately selected depending on the need of the facility.

Minimize the production of surgical smoke

Tissue ablation should be avoided. Other than surgical smoke, the amount of dead tissue and risk of infection also increases with unnecessary tissue ablation. Over usage of the cautery or laser on a tissue results in excessive production of smoke. The surgical vision field of surgeons gets obscured and hence poses a potential risk to the patient (35).

Increase the efficacy of smoke evacuation

Proper evacuation and filter system must be used in order to avoid contamination of work environment. Regular portable suction devices may not help in evacuating the plumes completely and may also cause leakage of the gases back into the environment.

Adequate ventilation

The operating room should be equipped with positive pressure to facilitate easy escape of the gases produced within the operating room. The room should also allow entry of fresh air, in cases where the room is equipped with air conditioners, proper and repeated maintenance of the device especially the air filters are mandatory.

Prevention of inhalation

Higher quality filter masks or double masking may protect from the smoke produced. Routine surgical mask may not be as protective as masks with high quality filter. In addition, a smoke evacuation device or filter placed near (2 cm-5 cm) the electrocautery blade or on endoscope valves offers additional (and necessary) safety for operating personnel and patients.

The most commonly used mask is a simple surgical face mask, made of three layers. Such masks will achieve 95%-99% bacterial filtration efficiency (BFE) and 91%-95% particulate filtration efficiency (PFE) (8). The disadvantage of surgical masks (either ear-loop or tie) is that it fails in providing a snug fit therefore smoke or its constituents are inspired via those loose points. A suggested alternative is a respirator (8). There are three types of respirators N, R and P classes. N stands for nonresistant to oil, R for resistant to oil, and P for oil proof. N class respirators are designed in order to filter particles that are non-oil based. N95 masks can achieve >95% filter efficiency when tested with ∼0.3 μm sodium chloride aerosol. The Rand P types of respirators are designed for filtering any particles with oil-based liquid aerosols. Grade 100 respirators can achieve >99.97% filter efficiency when exposed to ∼0.3 μm aerosols (8).

### Table 2

**Risks of exposure to surgical smoke**

<table>
<thead>
<tr>
<th>Risks of exposure to surgical smoke</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Acute and chronic inflammatory respiratory changes (e.g., emphysema, asthma, chronic bronchitis)</td>
</tr>
<tr>
<td>• Anemia</td>
</tr>
<tr>
<td>• Anxiety</td>
</tr>
<tr>
<td>• Carcinoma</td>
</tr>
<tr>
<td>• Leukemia</td>
</tr>
<tr>
<td>• Cardiovascular dysfunction</td>
</tr>
<tr>
<td>• Colic Dermatitis</td>
</tr>
<tr>
<td>• Eye irritation</td>
</tr>
<tr>
<td>• Headache</td>
</tr>
<tr>
<td>• Hepatitis</td>
</tr>
<tr>
<td>• HIV</td>
</tr>
<tr>
<td>• Hypoxia or dizziness</td>
</tr>
<tr>
<td>• Laceration</td>
</tr>
<tr>
<td>• Lightheadedness</td>
</tr>
<tr>
<td>• Nasopharyngeal lesions</td>
</tr>
<tr>
<td>• Nausea or vomiting</td>
</tr>
<tr>
<td>• Sneezing</td>
</tr>
<tr>
<td>• Throat irritation</td>
</tr>
<tr>
<td>• Weakness</td>
</tr>
</tbody>
</table>

CONCLUSION

Dentists and assisting staff should be educated about the potential risks of surgical smoke. In comparison between Laser plume and electrosurgery smoke, the electrosurgical smoke seemed to be potentially more hazardous than laser smoke. The operating room should be equipped with proper evacuation system. Usage of respirators should be made mandatory so that both the patient as well as the operator should be at minimal risk from the emissions that are released during any procedures. Effective methods to control this environmental occupational hazard, ultimately will be very beneficial to staff and patients in an operating.
REFERENCES