

Surgical smoke; an occupational hazard

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Abstract

Surgical smoke is part of the environment during operative and invasive procedures. Electric diathermy is a very important tool for a surgeon and is used in every surgical treatment nowadays. It assists the surgeon to dissect the tissue or enables securing haemostasis in lesser time and with larger delicacy. But at the same time, it has harmful effects on surgeon as well as patients.

Although there is a substantial amount of evidence and guidelines from various authors and societies, yet there are no clear policies and preventive measures towards surgical smoke handling.

This article presents potential harmful effects of surgical smoke and aims to build guidelines for the surgical personnel based on current evidence in literature.

Keywords: Surgical Smoke, Environmental Hazards.

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Introduction

Electric diathermy is a very important tool for a surgeon and is used in every surgical treatment nowadays. It assists the surgeon to dissect the tissue or enables securing haemostasis in lesser time and with larger delicacy. Through an electrode, it administers an electrical current at target tissue that raises the temperature of that tissue. This heating influence used is controlled by its wave form. A low-voltage, high-frequency current will upsurge the temperature, that causes tissue evaporation and this principle is engaged for cutting the tissue. A high-voltage, low-frequency current favours gradual heating influence that denatures the proteins inside the tissue, and so imposing the clotting of blood vessels.¹

During this cutting and clotting with the instrument, a by-product is formed, as a result of tissue evaporation that is termed as surgical smoke. It is also known by the names of aerosols, modality plume, cautery smoke or plume. Majority of the care providers, along with surgeons and hospital managers are unaware of the hazards of this

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smoke. Spearman et.al showed in their study that despite the fact that 72% operation theater personnel are of the view that precautionary measures taken to reduce the effects of surgical smoke on surgeons and doctors are inefficient, only 3 out of 98 surgeons use proper smoke extractors. They also showed that most of the personnel are not sure of the smoke hazards.²

Surgical smoke is formed by various devices e.g. electro cautery devices, optical laser ablation, inaudible scalpels, high speed drills, burrs and saws. It makes the vision of the doctor unclear, gives pungent odour, and spreads harmful substances in the surgical field. These materials may cause headaches, irritation of the eyes and secretion membranes, and potential harmful effects.³ Studies have shown that this smoke is connected to raised cardio respiratory mortality and morbidity.³ This article presents potential harmful effects of surgical smoke and aims to build guidelines for the surgical personnel based on current evidence in literature.

Composition

Surgical smoke causes mechanical and physical health problems that are related to its composition. Exposure to aerosol particles is linked to associated risk of respiratory disorders. Most of the harmful effects are arbitrated by carcinogenic volatile molecules like vinyl cyanide (a precursor of cyanide) and carbon monoxide gas. Rest of the health hazards are caused by particles, mainly those with a diameter at or below 2.5 μm (PM2.5), as these are identified to cause temporary hazardous health effects. Such particles breach the defence mechanisms of the upper respiratory tract and enter the alveoli and through these into the circulation. These digested particles get deposited into the very vital organs like brain, kidneys, liver and most importantly lungs. Though the potential effects of surgical smoke are acknowledged, however, smoke evacuation units don't seem to be used in numerous care centers.⁴ The results of a study by Stephenson et al. inculcated that viable infectious agents can be inhaled through electro cautery surgery. In an effort to corroborate these results, they think that studies showing the distances at which inhalation of smoke is safe and range of intensities at which viral DNA can survive should be determined. Stephenson et al stated further that efficient smoke evacuators in the

Table: Commonly found chemicals in surgical smoke.

Benzene	Acrylonitrile
1-Decene	Benzonitrile
2,3-dihydro indene	Indole
Ethyl benzene	Pyrrrole
Ethnyl benzene	Formaldehyde
Styrene	Benzaldehyde
Toluene	Furfural
Acetonitrile	Hexaecaonic acid

operating room (OR) are direly needed and everyone in the team should abide by the recommendations in order to avoid the harmful effects of the smoke.⁵ There is a vast number of evidence that HIV and HBV remain viable in smoke emitted from the devices as they have been identified in smoke of CO₂ ER, ND:Yag laser. It is found that HIV DNA can survive for 14 days in smoke generated by laser. Another study found a very high incidence of nasopharyngeal lesions in surgeons working with Carbon dioxide laser.⁶ A case study found that a surgeon acquired Human Papillomatous virus from one of his patients.⁷ Although these findings showed that inhalation of the smoke poses the OR personnel to various diseases, but these studies do not prove the causality and transmission, hence it can be stated that they do not provide enough evidence.⁸

Along with the mobile infectious particles, smokes emitted from the surgical devices also contain particles and chemicals (around 150) that can cause other harmful effects on the body. Few to mention are irritation of eyes, nose and pharyngeal irritation, obstructive pulmonary disease, dizziness, leukaemia and cardiovascular diseases.⁹

**Figure-1:** Smoke evacuator.

Recommendations

Currently there are no precise precautionary measures for the prevention of the surgical smoke which is posing everyone working in OR at the verge of harmful consequences.

◆ Minimal Production of the smoke

The ablation of tissues should be kept to minimum as it leads to increased necrotic slough and thus increased predisposition to infections in addition to excessive surgical smoke production. Also increased smoke can cause blurring of image in laparoscopic surgery, which poses patient on the verge of iatrogenic injuries.¹⁰

◆ Efficient smoke evacuation systems

Certain surgical procedures produce small amount of surgical smoke, e.g., Tonsillectomy, Nasal procedures, Ear surgery, Hernia surgery, Orthopaedic procedures and Breast Biopsy. During these surgeries, hand held suction should be placed at a maximum distance of 5 cm form the smoke producing device and the suction should have 0.1 micron filtration capability to ascertain maximum particulate suction, as well as visibility could be enhanced.¹¹

In surgical procedures, where an enormous amount of smoke is produced due to increased tissue dissection, a smoke evacuator must be used, e.g., Abdominal procedures, mastectomies, major limb surgery, thoracic surgery, neck surgery and joint replacement surgery. During these surgeries, which produce larger amount of smoke, following measures should be taken:

There should be a smoke extracting device having a probe connected with tubing for extracting smoke only, while the standard suction device should only be used to evacuate fluids.

Filters of these smoke evacuation devices should be cleaned or renewed on regular basis.¹²

◆ Smoke evacuation devices

According to The National Institute of Occupational Safety and Health (NIOSH), general room ventilation is not able to capture all the particulates at the source. So they recommend the use of local exhaust ventilation (LEV), i.e., portable smoke evacuators and room (wall) suction systems in addition to general room ventilation. They also proposed that the smoke evacuator should have a capture velocity of 100 to 150 feet per minute at the inlet and it should utilize a High Efficiency Particulate Air (HEPA) filter or equivalent. The two main LEV methods used commonly for the control of surgical smoke in healthcare systems are portable smoke evacuators and

room suction systems.¹³

◆ Smoke evacuators consist of a suction unit (vacuum pump), filter, hose, and a nozzle. These evacuators must have efficient particle extraction ability and always be used according to the manufacturers' instructions for utilization in best possible way. A capture velocity of about 100 to 150 feet per minute at the inlet nozzle is generally said to be optimum for good efficiency. It is necessary to select a filter that is useful enough in collecting the contaminant particles. A High Efficiency Particulate Air (HEPA) filter or equivalent is recommended for trapping particulates. Various filtering and cleaning processes also exist that remove or inactivate airborne gases and vapours. These filters and absorbers, which are being utilized to reduce surgical smoke in OR require a great deal of maintenance and should be renewed on regular basis. Moreover, once they have outlived their utility, they are considered as biohazard and require proper disposal.

◆ Room suction systems evacuate particles and smoke at a slower rate than the LEV and are meant to primarily capture fluids and aerosols rather than the gases. For them to evacuate, these should have proper filters and ensuring that filters get replaced regularly, can make evacuation efficient.

◆ Generally speaking, smoke evacuators are better than the suction systems in disposing the smoke generated in the operation theaters.¹⁴

Use of Masks

◆ Proper use of effective masks also constitutes the smoke prevention regimen. Surgical face mask is the most commonly used one with three layers, having 95-98% bacterial filtration efficiency and 91-95% particulate filtration efficiency. Bacterial Filtration Efficacy (BFE) is a measure calculated by exposing the mask with aerosol having bacteria of size 4 μm or larger. Particle Filtration Efficacy (PFE) is calculated by exposing masks with 0.1-0.3 μm aerosols¹⁵

◆ Surgical masks have the disadvantage that they do not fit snugly and leave spaces through which smoke can enter and possibly be inhaled by the surgeon¹⁶

◆ The second best option is a respirator. Health Care Particulate Respirators can be classified into N, R and P classes. N stands for not resistant to oil, R for resistant to oil, and P for oil proof. N class respirators are made to extract out particulates that are non-oil based. More than 95% filtration capacity is shown by commonly used N95 respirators when they are showered with $\sim 0.3 \mu\text{m}$ sodium chloride aerosol. The R and P types of respirators are used



Figure-2: N95 mask.

for the extraction of particulates in oil based aerosols. When showered with $\sim 0.3 \mu\text{m}$ aerosols, $<99.9\%$ filtration capacity can be achieved by the grade 100 respirators. Although there are not any specific recommendations provided by the NIOSH on utilization of the masks but during surgical procedures at least N95 respirators can be the safest option of all against surgical smoke emitted from the surgical apparatus like electro cautery and harmonics.¹⁷

Conclusion

Surgical smoke is a potential occupational hazard in healthcare facilities but there are no definite measures taken in general to avoid it. It is clear that LVE are the most efficient devices to make OR smokeless but it is not widely used.⁹ A survey demonstrated a lack of connection between awareness of surgical smoke hazard and a precise lack of preventive measures. This review can form the basis to build safety guidelines in electro surgery, ensuring the utilization of smoke evacuating devices and N95 masks. It can also enable preparing guidelines regarding education on the hazards of surgical smoke and recommended protective measures.¹⁸ All the employers and nursing staff should develop criteria and abide by these so a smoke free healthy environment can be created. Since the evidence of surgical smoke as an occupational hazard among surgical personnel has not

been well established, this narrative review will provide an insight about the direct impact of surgical fumes on the surgical team.

Limitations

The quality of evidence in this study is not of highest level and that's why a more high level and multi centered research is required to show evidence between transmission of diseases and other harmful effects of this surgical smoke.

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References

- Romano F, Gustén J, De Antonellis S, Joppolo CM. Electrosurgical Smoke: Ultrafine Particle Measurements and Work Environment Quality in Different Operating Theatres. *Int J Environ Res Public Health*. 2017; 14:137.
- Bree K, Barnhill S, Rundell W. The Dangers of Electrosurgical Smoke to Operating Room Personnel: A Review. *Workplace Health Saf*. 2017; 65:517-26.
- Pope CJ, Thun MM, Namboodiri M, Dockery D, Evans J, Speizer F, et al. Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. adults. *Am J Respir Crit Care Med*. 1995; 151:669-74.
- Karjalainen M, Kontunen A, Saari S, Rönkkö T, Lekkala J, Roine A, et al. The characterization of surgical smoke from various tissues and its implications for occupational safety. *PLoS One*. 2018; 13:e0195274-e.
- Fencel JL. Guideline Implementation: Surgical Smoke Safety. *AORN J*. 2017; 105:488-97.
- Harréus U. Surgical errors and risks - the head and neck cancer patient. *GMS Curr Top Otorhinolaryngol Head Neck Surg*. 2013; 12:Doc04.
- Hallmo P, Naess O. Laryngeal papillomatosis with human papillomavirus DNA contracted by a laser surgeon. *Eur Arch Otorhinolaryngol*. 1991; 248:425-7.
- Baggish MS, Poiesz BJ, Joret D, Williamson P, Refai A. Presence of human immunodeficiency virus DNA in laser smoke. *Lasers Surg Med*. 1991; 11:197-203.
- Steege AL, Boiano JM, Sweeney MH. Secondhand smoke in the operating room? Precautionary practices lacking for surgical smoke. *Am J Ind Med*. 2016; 59:1020-31.
- Da Silva RD, Sehr D, Molina WR, Moss J, Park SH, Kim FJ. Significance of surgical plume obstruction during laparoscopy. *JSL*. 2014; 18:e2014.00269
- Alp E, Bijl D, Bleichrodt RP, Hansson B, Voss A. Surgical smoke and infection control. *J Hosp Infect*. 2006; 62:1-5.
- Katoch S, Mysore V. Surgical Smoke in Dermatology: Its Hazards and Management. *J Cutan Aesthet Surg*. 2019; 12:1-7.
- Lee T, Soo JC, LeBouf RF, Burns D, Schwegler-Berry D, Kashon M, et al. Surgical smoke control with local exhaust ventilation: Experimental study. *J Occup Environ Hyg*. 2018; 15:341-50.
- Sato J, Kogure A, Kudo K. Effectiveness of activated carbon masks in preventing anticancer drug inhalation. *J Pharm Health Care Sci*. 2016; 2:28.
- Gao S, Koehler RH, Yermakov M, Grinshpun SA. Performance of Facepiece Respirators and Surgical Masks Against Surgical Smoke: Simulated Workplace Protection Factor Study. *Ann Occup Hyg*. 2016; 60:608-18.
- Janssen L, Zhuang Z, Shaffer R. Criteria for the collection of useful respirator performance data in the workplace. *J Occup Environ Hyg*. 2014; 11:218-26.
- Chapman LW, Korta DZ, Lee PK, Linden KG. Awareness of Surgical Smoke Risks and Assessment of Safety Practices During Electrosurgery Among US Dermatology Residents. *JAMA Dermatol*. 2017; 153:467-8.