LETTER TO EDITOR CODEN: AAJMBG

Surgical smoke: A silent hazard in healthcare

Received: 18th March 2020; ***Accepted:*** 25th June 2020; ***Published:*** 01st October 2020

Dear Editor:

Surgical smoke, known by various names such as surgical plume, smoke plume, diathermy plume and cautery smoke is the vaporization of substances, caused by thermal destruction of tissues using lasers and other energy-based electrosurgical devices [1]. Electro-surgical devices have become an integral part of surgery by virtue of their efficiency in improving hemostasis and minimizing duration of surgery [2]. Hence, the problem of surgical plume is here to stay.

Surgical smoke is composed of gaseous toxic compounds, bio-aerosols, dead and live cellular material such as blood and fluids, carbonized tissue, infectious organisms such as human papilloma virus(HPV), human immunodeficiency virus (HIV), Staphylococcus, Corynebacterium and Neisseria [1-2] Approximately 150 chemicals such as benzene, toluene, formaldehyde, acetaldehyde, butadiene, carbon monoxide, methane, polycyclic aromatic hydrocarbons, and hydrogen cyanide have been identified in surgical plume [1-3].

Most particles generated in surgical plume are within respirable size range. Studies analysing the content of plume have identified that electrosurgery generates the smallest aerodynamic size particles in the size range of <0.07-0.1 microns, followed by laser tissue ablation (approximately 0.3 microns) and ultrasonic scalpels (0.35 to 6.5 microns) [3].

Over half million healthcare workers worldwide are exposed to surgical smoke annually [1]. Apart from obscuring the view of surgical field and being associated with noxious odour, surgical plume poses substantial health hazards to patients, peri-operative team members and organisational observers [1-2]. Minimal exposure can induce nausea, dizziness, lacrimation, head ache and irritation of eyes, nose and throat among health care workers and patients [3]. At high concentrations plume can cause significant respiratory morbidity [1-3]. More than three-fourths of the particles generated are less than 1.1 microns and hence are capable of being deposited in alveoli disrupting the gas-exchange process [3].

Chronic exposure to certain particles of plume has carcinogenic potential due to cumulative effect [1-3]. In addition, there is a high risk for transmission of viable organisms such as HPV while operating on infected tissues predisposing the health care team to serious infections [1-3]. Patients undergoing laparoscopic procedures are at significant risk due to absorption of ultrafine particles of plume into circulation through peritoneum [2-3]. Absorption of the particles by red blood cells can result in carboxyhemoglobinemia and methemoglobinemia and resultant hypoxic stress [2-3].

Surgical smoke has been recognised as a potential occupational hazard in health care. General room ventilation and smoke evacuation systems (SES) are recommended to be the first line of protection against surgical smoke exposure [2-3].

Table 1 summarises the preventive and protective measures recommended against surgical smoke.

Table-1: Recommended measures for prevention and protection against surgical smoke

Educational measures	Dissemination of information on hazards of surgical smoke and safety measures to health care staff at all levels [4] Education on minimizing plume generation by avoiding unnecessary tissue ablation Reinforcing the responsibility of health care personnel in ensuring patient safety [3] Periodic refresher and reinforcement training programmes on use of SES and personal protective measures [2] Ensuring use of fit-tested N95 respirators during electrosurgical procedures to protect respiratory tract [2] Ensuring care of eyes (protective glasses) and skin (coat and gloves) during all minor or major procedures [2]
Engineering measures	**General ventilation** • Good general ventilation or dilution ventilation is a basic minimum requirement where SES is unavailable [1-2,4] • Mechanical exhaust ventilation for procedures with low, uniform rate of plume generation [2-4] • Minimum of 15-20 air exchanges per hour with use of HEPA air filter or ventilation with laminar air flow [2,3,4] • General ventilation alone is not effective without SES
	Local exhaust ventilation (Room suction systems and Mobile SES) <u>Room suction systems</u> • with air movement of about 2 cubic feet/minute, primarily captures liquid rather than particles or gases [4] • requires use of appropriate in-line filters which are cleared regularly and disposed safely [4] • useful for low plume output procedures and outpatient settings where minor procedures are performed [4] <u>Mobile smoke evacuation systems</u> • Should be employed in all procedures which generate plume (major or minor) [4] • Essential in high plume output procedures [2-4] • A capture velocity of about 100 to 150 feet per minute at inlet nozzle is recommended [4] •Should always be held less than an inch away from source of plume to facilitate effective evacuation [4] •Triple filter system (a pre-filter to capture large particles and fluid, an Ultra-Low Particulate Air (ULPA) filter to capture small particulate matter, a charcoal filter that absorbs toxic gases and odors) should be preferred to capture all types of particles [2,3] <u>Laparoscopic Smoke evacuation systems</u> •Individual SES with special ULPA filters (0.1 microns) should be connected to trocar during entire procedure to prevent leakage of plume into external surgical environment [2,3,4] •Particular care in smoke evacuation at end of procedure when pneumoperitoneum is released [3]
Administrative measures	Implementation of Standard safety precautions for operation theatres [4] Monitoring of level of smoke exposure in individual procedures [4] Ensure SES use in all procedures regardless of amount of plume [4] Ensure standard precautions for infectious or hazardous waste, during change of filters, cleaning and disposal of equipments [2-4] Periodic audits to monitor compliance followed by corrective measures [4] Mandatory pre-induction and periodic training programmes [2] Record maintenance [2] Notification of adverse exposures or events Interdisciplinary approach involving all stakeholders including administrators, surgeons, physicians, anaesthetists, perioperative nursing personnel, scrub persons and infection prevention committee [2] Pre-employment and Periodic respiratory assessment of health care personnel Incorporating ergonomic designs for efficient smoke evacuation at source (electrocautery devices with suction at tip, smoke evacuation system with in-built filtration system)

Three broad barriers have been identified in the prevention and control of surgical smoke as a significant health hazard, namely, inadequate awareness and compliance towards protective measures; efficiency of smoke evacuation systems and lack of universal guidelines for surgical smoke safety [5-8]. Lack of adequate awareness and compliance towards protective measures has been reported from research from across the world. Significant among them is a large-scale study by National Institute for Occupational Safety and Health (NIOSH), where only 14% of those exposed during electrosurgery and 47% of those exposed during laser surgery reported use of local exhaust ventilation (LEV) during procedures [5].

Considering the high use of electrosurgical and laser procedures, predominantly performed at out-patient settings, the Indian Association of Dermatologists, Venereologists and Leprologists recommend use of smoke evacuator with High-Efficiency Particulate Air (HEPA) filters while treating verrucae or large epidermal naevi apart from use of surgical masks [4]. But smoke evacuators are rarely used in dermatology clinics [4]. Diathermy plumes have also been found to contain ultrafine particles which might be teratogenic and carcinogenic and SES are less likely to be used with diathermy [6]. McQuail et al have reported inadequate awareness on diathermy plume among surgeons [6]. Increased knowledge and training, positive perceptions about complexity of recommendations, perception of hazards, increased specialization, interconnectedness and leadership support in larger facilities were identified to be the key factors influencing positive smoke control practices [7]. The common barriers hindering compliance include lack of equipment, noise, physician resistance and staff member complacency [7].
Efficiency of SES varies in different studies. An experimental study by Kocher et al identified persistence of compounds such as butadiene and benzene above permissible limits despite SES use [8].

Despite the proven health hazards, very few countries and organisations have framed guidelines for surgical smoke safety. American National Standards Institute (ANSI) has prescribed minimum standards for safe use of lasers in health care facilities [9]. Centres for Disease Control and Prevention (CDC), European Operating Room Nurses Association (EORNA) and Association of periOperative Registered Nurses (AORN) have prescribed best practices for surgical smoke safety [1-3]. Countries such as Canada, Denmark, Australia, New Zealand and United Kingdom have enacted specific regulations to eliminate or contain surgical smoke, reinforcing the responsibility of employers to provide local exhaust ventilation and smoke evacuators along with periodic training programmes to ensure a smoke-free environment for health care workers [10]. But established guidelines and standards are conspicuously lacking from most countries of the developing world.

Health care organizations have a responsibility to provide a secure and healthy workplace. This assumes greater importance in view of the current COVID-19 pandemic with health care professionals at highest risk of infection during aerosol-generating procedures. With no organised regulations in most developing and under-developed countries, there is an urgent need to devise standard operational procedures to minimise or prevent smoke exposure. New energy-based surgical tools which produce fewer plumes need to be devised. There should be emphasis on research to assess awareness and adherence to smoke safety measures and design of more effective systems.

Financial Support and sponsorship: Nil

Conflicts of interest: There are no conflicts of interest.

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Cite this article as: Mani G, Surgical smoke: A silent hazard in healthcare. *Al Ameen J Med Sci* 2020; 13(4): 309-312.

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