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It is time for a more cautious approach to surgical diathermy, especially in COVID-19 outbreak: A schematic review

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ABSTRACT

Background: Many surgeons are unaware of the risks posed by the surgical diathermy. Apart from the numerous chemicals, surgical smoke had been shown to harbour intact bacterial and virus particles especially COVID-19 in the current time.
Objective: To identify the inhalational, infectious, chemical, and mutagenic risks of surgical smoke and suggest evidence-based hazard reduction strategies. Also to cogitate on the very high risk of viral spread by the use of surgical diathermy in COVID-19 outbreak.
Methods: A review of articles indexed for MEDLINE on PubMed using the keywords surgical smoke, diathermy, electrocautery, surgical smoke hazards, smoke evacuator, and guidelines for surgical smoke safety was performed. The review included evidences from 50 articles from the dermatology, surgery, infectious disease, obstetrics, and cancer biology literature.
Results: There are risks associated with surgical smoke. Although some surgeons were aware, majority were not keen in the hazard reduction strategies.
Conclusion: Many chemical and biological particles have been found in surgical smoke. It is highly recommended to follow the standardised guidelines for surgical smoke safety. Surgical smoke carries full virus particle(such as COVID-19 virus), it is strongly recommended to minimise or avoid electrocautery during the COVID-19 outbreak.

1. Introduction

Surgical diathermy, also known as electrocautery is a useful and common surgical technique for tissue ablation. Here, an alternating current is passing through a resistant metal wire electrode, generating heat which is then applying to living tissue to achieve the hemostasis or varying degrees of tissue destruction.[1] Heating of tissues causes vaporisation of protein and fat which results surgical smoke[2] which contain particles from combustion and numerous chemicals like hydrocarbons, acrylonitrile, phenols and fatty acids and biological particles, viruses, and bacteria which are known to be potentially hazardous. Applications of high-frequency electrocautery in cutting and coagulation modes produce odorous smoke from tissue pyrolysis. Thus surgical smoke is a by-product of the heat produced by electrosurgical tools.

Most orthopaedic surgeons are often unaware of the risks posed by the surgical diathermy in their daily work environment. This issue is potentially harmful to cause cancer risk on long-term exposure among surgical personnel.[3] Surgical smoke had been shown to harbour intact bacterial and virus particles.[4,5] In COVID-19 outbreak scenario, the use of surgical diathermy has to be minimised or avoided due to the very high risk of viral spread among operating room personals.

2. How does surgical smoke become dangerous?

Information on the hazardous nature of surgical smoke is not new. Now, a multiplicity of chemical and biological hazards have been identified in surgical smoke. It is reported that surgical smoke has mutagenic effects as well.[6] Surgical smoke contains contaminants such

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as hydrocarbons, acrylonitrile, phenols, fatty acids, nitriles and carbon monoxide and viable cellular elements.[7,8] The main chemical in surgical smoke is polycyclic aromatic hydrocarbons(PAHs). Amongst these PAHs, benzopyrene(BaP) is the most significant carcinogenic compound.[9] Benzopyrene is often used as an indicator of cancer risk for target populations. Studies have shown that higher cauterisation temperatures produce more harmful chemical components while lower temperatures produce more cell particles ([5]). It is also found that different electrosurgical techniques produce different amounts of surgical smoke.[10] The chemical composition of surgical smoke also varies by the type of tissue dissected. Muscular tissue produces aldehyde and ketone; liver and fatty tissue liberates carbon monoxide and hydrocyanic acid; epidermal tissue produces xylene, toluene, and ethyl benzene.[5]

Studies have been showing various pulmonary changes when exposed to smoke plumes.[11,12] The size of particulates and concentration of chemical or cellular particulate in surgical smoke is a critical issue. Particulates can range from 10 nm to 100 μm. Smaller the particles, the deeper inhaled into, particles 7 μm or smaller can be deposited in the alveoli.[10] Electrocautery produces more surgical smoke than laser or ultrasonic scalpel. Electrocautery led to the formation of smaller particles (0.07 μm), where as lasers and ultrasonic devices lead to the formation of larger particles (0.31 μm–6.6 μm). Smaller particles are chemical health hazards and larger particles are acting as biological hazards([5]).

Studies have shown similarities between surgical smoke and the adverse effects of air pollution and passive cigarette smoke.[5,13] Surgical smoke also contains a variety of cellular particles which harbour contagious, viable malignant cells, and even to contain live bacteria and viruses. Different studies have clearly mentioned many viruses like HIV, infectious polio virus, human papilloma virus(HPV) and hepatitis B virus (HBV) are present in surgical smoke,[3,4,14,15] this knowledge is relevant in COVID-19 outbreak. There for, it is possible to have viruses like COVID-19 in cellular particles.

3. Deleterious effects to surgeons and or personal

Surgical smoke is a visible suspension of water vapour, volatile organic compounds and other organic matter of biological origin released when the instruments raises intracellular temperatures > 100 °C.[16] The cutting mode can create a higher tissue temperature in a shorter period of time, resulting in rapid expansion and explosive vaporisation of intracellular contents.[17] While coagulation is performed using waveforms with lower average power, heat generating is insufficient for explosive vaporisation. So the risk of surgical smoke production is more with cutting mode and will be absent or negligible with coagulation mode. Surgical smoke is a nuisance because it has a repulsive odour and can obstruct the surgeon's view of the surgical site. Individuals in the operating room, including surgeons, surgical technicians, nurses, anaesthesiologists, and others, are exposed to surgical smoke annually.[18]

3.1. Infectious hazards

Infectious particles in surgical smoke have been studied extensively and viral transmission has been well demonstrated in animal studies.[7,19–23] Smaller particles in surgical smoke are chemical health hazards and larger particles are acting as biological hazards.[5] Hence, viral DNA content seems to be higher in laser and ultrasonic smoke than in electrocoagulation smoke.[25] Since surgical smoke contains many viruses[4,14,15] many of the surgeons acquired their infection through it.[21] In this context, we cannot ignore the possibility of spreading COVID-19 through cellular particles in surgical smoke.

3.1.1. Direct physical injury

Direct physical injuries like alveolar congestion, interstitial pneumonia, and emphysematous changes by surgical smoke have been demonstrated in animals. The chemicals contained in the surgical smoke are pulmonary irritants which have resulted to cause coughs, burning throats, sneezing, and rhinitis in surgeons and OR Personal(11). This may have a significant impact on the health and safety of everyone in the operating room, because these compounds pose a potential health risk.[11] Animal studies have shown that the use of 0.1-m ultra-low permeability air filters does not cause substantial parenchymal damage.[24]

3.1.2. Chemical and mutagenic effects

Surgical smoke produced by electrocautery will produce more harmful chemical components. Some of the chemical substances, such as benzene, formaldehyde, acrolein, CO and hydrogen cyanide, are also present in the smoke released by laser tissue ablation.[30] Benzene can induce headache, dizziness, nausea, and irritation of the mucous membranes.[26] What's more, it also contained carcinogens and teratogens(11). Toxicity equivalency factors (TEFs) were recommended for calculating the relative toxicity of individual PAHs to BaP for the purpose of simplifying risk assessment.[27] Acute deleterious effects of exposure to surgical smoke includes eye, nose and throat irritation, headache, cough, nasal congestion, asthma and asthma-like symptoms.[2,18,28,29] Chemicals present in surgical smoke may cause cancer in humans.[5] Although there have been no human studies on the carcinogenic effects of smoke, surgical smoke has been shown to be carcinogenic in vitro.[30]

It was calculated that the total mutagenicity from surgical smoke condensates generated for 60 s from 1 g of tissue was equivalent to that of 3 (in the case of CO2 lasere induced smoke) to 6 (in the case of electrocautery-induced smoke) cigarettes.[26] Although direct physical injury and carcinogenesis have been well demonstrated in *in vitro* and animal models, it is difficult to describe the long-term effects on humans due to the inherent time lag and the inability to prove causality.[30] Some of the risks are theoretical, until there is evidence that disproves these risks to humans.

4. Deleterious effects to patients

Electrical shocks and burns are possible from electrocautery arise from a faulty grounding pad or from an outbreak of a fire.[31] This issue happens if the surface of the contact pad is small and the pad is disconnected from the radio frequency generator or through a metal implant.[32]Modern electrocautery systems have sensors that prevent similar injuries. There have also been reports of flash fires, especially in the case of increased oxygen concentrations of anesthetics.[33] The toxicity of surgical smoke may cause harm to patients.There have been no reports that surgical smoke exposure to patients can cause any obvious chronic diseases such as cancer or chronic obstructive pulmonary disease (COLD). Such diseases might be caused by accumulation processes. Diathermy can also cause tissue damage through energy transfer to the implanted spinal cord stimulation system, resulting in serious injury or death. Diathermy incision has many advantages compared with the scalpel because of reduced incision time, less blood loss, and reduced early postoperative pain.[34], but there are reports which show increased tissue damage and a significant reduction in the tensile strength of healing wounds.[35]

5. Current practices to reduce the risk

Although a reasonable body of research exists on the aspects of surgical smoke, little substantive data exist about the actual exposure patterns. Traditionally, the removal of surgical smoke through conventional ventilation and continuous hourly ventilation(Air changes per hour-ACH). The capability of 20 ACH can be able to remove hazardous substances below those of exposure standards.[36] It was described that conventional ventilation will work effectively if exhaust grills must be free of obstruction by equipment or furniture.[37] The use of specific suction or extraction measures for surgical smoke has been

recommended by many regardless of exposure duration or concentration level.[38,39] Smoke evacuation in the operating room has been highly recommended to minimise exposure.[3] High efficiency particulate air filters (HEPA) is another recommendation to reduce the hazards of surgical smoke. In HEPA contaminated air first passes through the operating room corner vents, and is then filtered and re-circulated in the operating room. HEPA efficiency and the air exchange rate determine operating room air quality.

The surgeon's, exposure to an average of 16 typical PAHs in the gaseous and particle phases were 1279 and 37 ng/m3, respectively. Though gaseous PAH concentrations were 30 times higher than those associated with particles, it should be noted that high molecular weight PAHs often result in higher carcinogenic effects.[40] Though the HEPA can remove particles in recirculated air, gaseous pollutants may penetrate through filters and accumulate in the OR air. So the effectivity of removing surgical smoke in operating room should be emphasised to minimise the potential adverse health effects.

Hazards and risks are identified and risks are managed based on control measures from best to least effective by methods like elimination, substitution, isolation, engineering controls, administrative controls, and personal protective equipment.[41] Multiple precautions like use of a standard surgical mask, laser or high filtration mask, masks coated with nanoparticles, operating room ventilation guidelines, and use of wall suction have been using to reduce the health hazards, but each one has its own limitations. Therefore, it is strongly recommended to use smoke extraction devices. In view of surgical smoke has been shown to harbour intact virus particles, it can very well carry COVID-19 like viruses. So it is mandatory to minimise or avoided electrocautery especially in COVID-19 outbreak, as it was recommended in Middle East Respiratory syndrome outbreak(MERS).[42] A negative-pressure operating room is the optimal environment to prevent all airborne viruses including COVID-19, bacteria, fungi, yeasts, gases, volatile organic compounds, small particles and chemicals spreading to adjacent areas.[43]

Surgical masks do not work well at filtering submicrometer-size particles, and a poorly fitted mask greatly compromises the performance. The bacterial filtering efficiency of N95 respirator is superior to that of the surgical mask, and this fact is especially true in environments with high concentrations of airborne bacteria. Although N95 respirators have higher filtration efficiency in a laboratory environment, there is insufficient data to determine whether N95 respirators are superior to masks in protecting medical staff from infectious infections.[44–46]

6. Recommendations to reduce it's deleterious effects(NIOSH)[28]

The National Institute of Occupational Safety and Health (NIOSH) conducted a detailed study and said that little is known about the health effects of long-term exposure to surgical smoke(28). NIOSH is the Federal agency responsible for conducting research and making recommendations for preventing work-related illness and injuries.

A. Employees have to use local exhaust ventilation (LEV) for all procedures where surgical smoke is generated. Smoke evacuators should be used in situations where considerable plume is generated and room wall suction systems should be used for controlling small amounts of smoke when there is adequate room air ventilation.[28,29,47]
B. Train employees on the hazards of surgical smoke and methods to minimise exposure prior to working in areas where surgical smoke is generated.[48]
C. Ensure that procedures that address the hazards of surgical smoke are available(47).
D. Use a properly fitted, filtering face piece respirator like N95 mask rather than a ordinary surgical or laser mask, especially in situations where LEV is lacking or not functioning properly. Respiratory protection should be at least as protective as a fit-tested N95 filtering face piece respirator when working with known disease transmissible cases (Viral infections like HPV, COVID-19) and/or during aerosol-generating procedures or with aerosol transmissible diseases (e.g., TB).[47,49]

It is interesting to noticed in a survey by NIOSH that only half (47%) of respondents reported that LEV was always used during laser surgery and even fewer (14%) reported that LEV was always used during electrosurgery.[28] Surgical smoke safety guidelines will establish a safe environment for surgeons, individuals or patients."

7. Future perspectives

Though the concern about respiratory exposure is warranted, little evidence is available to determine actual exposure levels. This lack of evidence is compounded by a lack of research comparing electrosurgical techniques, type of surgery, and ACH. Future researches have to focus on surgical smoke exposure levels in operating room while performing a specific type of surgery, using a specific electrosurgical technique and the ability of air changes per hour(ACH) and other administrative measures to reduce surgical smoke exposure to acceptable levels.[36] Cold steel scalpel has been the instrument of choice for surgical incisions because of accuracy, and predictable tissue damage.[50] However, the use of cold steel scalpel must be accompanied by electrocautery to maintain hemostasis and a clear surgical field. Furthermore, research is needed on a equally or better alternative to electrocautery, which can also reduce incision time, bleeding, and thermal tissue damage might be beneficial as well. The ACE Blade and Mega Power Generator (ACE electrosurgical system) is a next-generation electrosurgery system that is intended for use in a broad range of surgical procedures requiring the use of electrosurgery(50).

8. Conclusion

Many chemical and biological particles have been found in surgical smoke. They have potentially serious occupational hazards, especially the viruses like COVID-19. The surgical smoke exposure for surgeons and anaesthetist have been fully investigated by measuring the PAH concentrations in both the gaseous and particle phases in their breathing zones. Efficient smoke extractors in the operating room or high-efficiency masks are suggested to minimise potential health hazards. Insufficient knowledge on these regards demands the need for further investigation and research. So further studies are needed for its effects on duration of exposure, the composition of surgical smoke produced by different electrosurgical techniques and the impact of ACH.

We need to receive education about the hazards of smoke plume to raise awareness of the health risks of surgical smoke. Each of the many precautions currently available has its own limitations, so smoke extraction devices are very much recommended than any other. It is highly recommended to follow the standardised guidelines for surgical smoke safety. Since it has been proven that surgical smoke carries full virus particle(such as COVID-19 virus), it is strongly recommended to minimise or avoid electrocautery during the COVID-19 outbreak. Surgical smoke poses numerous risks to the surgeon, including the transmission of infectious diseases, mutagenicity, and direct physical injury. Smoke safety guidelines would establish a safe environment for the surgeon, OR personal, and patient. The usage of surgical diathermy is mainly for the ease and comfort of the surgeons and not for any direct benefit of the patient. We hope to invent an equivalent or more effective alternative to electrocautery in the near future, which will not causes any of the above harmful effects. Till then we have to reduce the it's usage judiciously.

Declaration of competing interest

We the authors hereby declare that we do not have any financial and other conflicts of interest that might bias the work. We have not published or submitted this article elsewhere. We also declare that it is not under consideration for publication with any other journal.

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