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The Surgical Smoke

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Abstract: ***Surgical smoke is the gaseous by-product formed during surgical procedures. Most surgeons, operating theatre staff, and administrators are unaware of its potential health risks. Surgical smoke is produced by various surgical instruments including those used in electrocautery, lasers, and ultrasonic scalpels. Potential risks include toxicity from harmful particles liberated from the surgical instruments which may produce short-term as well as long-term hazardous effects on the human body. It may affect the operator, operating theatre staff, and patients also. Minimization of the production of surgical smoke and modification of any evacuation systems are possible solutions. Different methods are used for the evacuation of surgical smoke which includes surgical masks, proper ventilation, evacuation systems, etc. The discussion about the most hazardous product of surgical smoke and the best method of protection against surgical smoke is carried out risks.***

Keywords: Surgical smoke, surgical procedures, operating theatre

1. Introduction

What is smoke? any bioaerosol-containing gaseous by-product, which includes both alive and decaying cellular material, is referred to as "smoke." The end result of electrocautery and laser tissue ablation is mentioned in medical journalism as a smoke plume & even aerosol. Ultrasonic scalpels produce what is usually termed as plume, aerosol, and vapor. Surgical smoke's potential for danger has recently become a cause of worry. Electrocautery and laser surgical smoke are both created using a similar basic pathway. The target cells are vaporized in the treatment (cut, coagulate, vaporize, or ablate tissue), & tiny particles are discharged into the air or lungs as a consequence of the membranes rupturing. Smoke is created when lasers & electrosurgical pencils, which are frequently used for separation and hemostasis through surgery, come into touch with human tissue. Like smoke from cigarettes, surgical smoke can be observed and odored. It smells bad and may betagenic, according to research. Lasers are used to cut blood vessels or remove damaged tissue. When compared to a regular scalpel, electrosurgical pencils have many advantages for surgeons and are used in practically all surgical procedures to halt bleeding at the incision site. Surgical smoke is harmful as it contains more than 150 dangerous compounds, as well as cancer- and mutagenic-causing cells that exist in surgical smoke. There are poisonous vapors and fumes present, including benzene, hydrogen cyanide, formaldehyde, bioaerosols, dead and living cells, blood, and viruses [1]. Smoke from surgery contains active viruses like the human papillomavirus and causes respiratory illnesses, asthma, and allergy-like symptoms in addition to these other health issues. Inhaling surgical smoke has been shown to transfer the human papillomavirus from patients to medical personnel [2]. There are various types of chemicals present in surgical smoke which are hazardous to humans, most abundantly found are phenols, nitriles, fatty acids, and hydrocarbons. In, one of the chemicals is acrylonitrile it is colorless and has carcinogenic properties as it forms hydrogen cyanide [3]. In order to prevent tissue oxygenation, carbon monoxide and hydrogen cyanide work together synergistically [4]. Surgical smoke exposure is associated with higher mortality and detrimental effects on the respiratory and cardiovascular systems [5]. The smoke produced in surgeries can be hazardous on different levels according to the level of exposure i.e duration of exposure & amount of time spent in the smoke. Everyday effects of smoke on the team of surgeries average out to be exposed to 27–30 unfiltered cigarettes' worth of smoke. The hazards related to surgical smoke also rely on the technique used by the surgeon, the procedure, the pathology of the tissue (such as the energy type delivered, the intensity of the procedure & the power levels employed), & the existence of particular germs or viruses. Cutting, coagulation, or ablation are other factors that can impact the surgical smoke's volume and quality. The aim is to illuminate surgical smoke, & what hazardous properties it causes on the clinicians in the operatory, and its effects which depends on different factors which will be further explained in the article. Based on the most recent information originating in the literature, this article discusses the probable dangers of smoke produced during surgeries and offers advice to the operating community.

2. Review

Smoke contains harmful substances and causes hazardous effects on the body. Smoke production by smoke-producing devices produces desired effect on the tissue which is required to carry out the surgical procedure (for example- hemostasis, ablating or dissecting the tissue, maintaining a clear field, and easy to use.)

Different devices are used to produce surgical smoke. One of the primary devices used to produce surgical smoke is electrosurgery devices, lasers known as cautery, ultrasonic scalpels, etc. These devices are used extensively in the

surgical field and have been known to ease the work of the clinician but also have hazardous harmful effects on the clinicians and the subordinates in the operatory. Acetaldehyde, acrolein, acetonitrile, benzene, formaldehyde, polyaromatic hydrocarbons, styrene, toluene, xylene, and carbon monoxide are some of the toxic chemicals found in surgical smoke, are what cause the harmful effects of smoke produced during surgeries. Types of equipment which produces surgical smoke are described below along with any potential health risks they may provide.

Potential Hazards due to Surgical Instrument Producing Surgical Smoke

Electrosurgery

Devices are used in laparoscopic surgical procedures. Electrosurgery causes both mechanical and electrothermal trauma to the tissues. An offensive odor that is distinct in the operating room is caused by electrothermal damage as well as the burning of proteins and lipids in the operatory. Furthermore potential long-term impacts, these substances could result in headaches, irritability, and discomfort in the throat, nose, and eyes (6). Hydrocarbons (carbon monoxide), phenols, nitriles, fatty acids, and acrylonitrile are the most frequent compounds in electrocautery smoke; acrylonitrile and carbon monoxide is the most dangerous of these. It was found that whereas the smoke created by cauterizing adipose tissue had higher measures of aldehydes and lower concentrations of toluene, the smoke produced by cauterizing skin tissue contained more concentrations of toluene, ethylbenzene, and xylene. Higher quantities of toluene, ethylbenzene, and xylene were recognized in the smoke produced by cauterizing epidermal tissue, while toluene levels were lower and aldehyde levels were higher in the smoke produced by cauterizing adipose tissue (7). Anoxic environments may produce electrosurgical smoke with a distinct chemical makeup (8). During electrocauterization, there is the formation of carbon monoxide forms due to tissue dissection (9). Laparoscopic operations may result in incomplete combustion or the presence of carbon dioxide as the cause of this. Carbon monoxide entry in the bloodstream creates a pathway for systemic poisoning. When carbon monoxide increases in the blood it combines with hemoglobin and becomes a potential competitor to oxygen and reduces the oxygen-carrying capacity of hemoglobin by combining with Hb and forming carboxyhemoglobin (HbCO) and methemoglobin (Met Hb). In cardiovascularly compromised patients such conditions may lead to cardiac impairment (3)(9). A volatile, colourless substance called acrylonitrile creates cyanide. The toxic effect of acrylonitrile is due to the toxic effect of cyanide. The skin and lungs can quickly absorb cyanide and may cause injury by preventing the use of intracellular oxygen by suppressing cytochrome oxidase action (10). Long-term exposure has been related to a greater occurrence of malignancies in humans and has been shown to induce cancer in experimental animals. When skin is exposed to acrylonitrile repeatedly or for an extended period of time, dermatitis and irritation may result (11). Another dangerous component of surgical smoke is benzene, which can irritate the nose, sight, and lungs & cause light-headedness, nausea, and other health problems. Low concentrations and prolonged exposure can cause a variety of blood diseases, from leukemia to anemia. Numerous blood disorders linked to benzene exposure may go unnoticed (12). There has been a drive to tighten the regulation of surgical smoke exposure due to growing studies and understanding the detrimental properties of surgical smoke on operating room staff (13). PELs for workers have been established by the American Occupational Safety and Health Administration (OSHA, www.osha.gov). These chemicals' health impacts are a result of the exposure that exceeds these PELs. PELs are intended to stop these negative health consequences from happening and to create a secure working environment for those who may be exposed to these chemicals (12).

Ultrasonic Devices

The use of ultrasonic instruments for hemostasis and dissection has grown in popularity. Tissue is removed during ultrasonic dissection through quick mechanical action (14). One of the ultrasonic devices is an ultrasonic scalpel which may produce surgical smoke in the operatory.

Ultrasonic Scalpel-

An ultrasonic scalpel's active blade vibrates 55,500 times per second, creating frictional heat as it comes into touch with the tissues. A coagulum, an adhesive material that plugs the vessel, is created when the protein in the tissues is denatured, as a result of this frictional heat. Using an ultrasonic scalpel, vessels can be severed right away after being sealed. The plumes produced by ultrasonic scalpels contain significant amounts of cellular debris ($>1*10^7$ particles/mL) (12). The concentration of liquid such as blood and blood by-products, along with tissue was produced with an ultrasonic scalpel. The method is known as low-temperature vapourization and the ultrasonic scalpel is stated to produce a "vapor" rather than smoke. This is concerning since cooler aerosols frequently have a higher probability of harboring infectious and viable material than aerosols with higher temperatures (15). Unfortunately, there is no consensus on the precise makeup of these aerosols because they have not been widely investigated (12). Some studies suggest that there is no evidence between the risk stood by aerosols produced by ultrasonic scalpel and aerosols generated by electrosurgical procedures but some suggest there was a non-significant tendency toward reduced amounts of all chemicals in the ultrasonic scalpel specimens when comparing them to diathermy samples (12)(16).

Lasers

The second most popular heat-generating tool used by surgeons is a laser. A "laser" technique is a way of producing light energy by light enhancement by radiation emission that has been triggered. An intense beam of light makes up this energy (14). The potential risk of laser-generated plumes (aerosol) has become more widely known. Many laser systems generate a plume of smoke including debris and vapor into the surrounding region when they contact the targeted tissue. The risks of spreading infection, dispersing viable tumor cells, and aerosolized carbonized material have all been considered (17). There are 2 different varieties of lasers commonly used CO_2 lasers and Nd: YAG lasers (3). The laser tissue ablation plume contains the chemicals benzene, formaldehyde, acrolein, CO, and hydrogen cyanide (12). Additionally, live particles, including biological components & erythrocytes, have been discovered in plumes, indicating their possibility for infection. CO_2 lasers ablate

tissue and the smoke generated from it consists of bacterial spores and viral infections. Several medical specialties employ the carbon dioxide (CO2) laser to evaporate, ablate, or cut tissue. Water effectively absorbs the lower infrared light energy that this device generates (10600 nm). Tissue has a fair amount of water, therefore the laser energy is easily converted to heat. Numerous plumes are produced, necessitating continuous suction through a filter system away from the procedure area (17). Viable particles are present in the plumes generated from the laser. Five coagulase-negative Staphylococcus strains were cultured on bacterial cultures on samples obtained from laser plume smoke during laser operations in thirteen patients. Of the 5 positive cultures, Corynebacterium and Neisseria were both present in one of the cultures (18). Along with bacterial infections, there is a chance of developing viral infections as well there are further discussions in which clinicians have developed viral infections due to surgical smoke which is harmful in nature. There are many pieces of evidence discussed below where there is the development of viral infections due to surgical smoke. By putting the laser plume directly into the calf's flesh, the same researcher later proved the laser plume's infectiousness (17). After using neodymium: yttrium-aluminum-garnet laser to treat a patient with anogenital condylomata brought on by human papillomavirus (HPV) infection, a surgeon reportedly experienced laryngeal papillomatosis. HPV types 6 and 11 were detected in the laryngeal papilloma tissues using in situ DNA hybridization, matching the patient (19). Intact DNA samples of the human papillomavirus (HPV) and the bovine papillomavirus (BPV) were found in 1988 in the CO_2, laser-treated human and bovine lesion (20). A study has shown infection of HIV through laser smoke (15).

Precautions Taken to Evacuate Surgical Smoke

Clinicians in the operatory can use several things to protect themselves from surgical smoke. In order to minimize exposure to surgical smoke, clinical staff become experts in what is feasible and employ the tools and expertise at their disposal. Proper operatory ventilation, surgical masks, wall suction, portable smoke evacuation systems, central smoke evacuation systems, and laparoscopic smoke evacuation are some of the ways that have been evaluated for decreasing surgical smoke in the operating room.

Surgical Mask

The initial persistence of the surgical mask has been to guard patients from illnesses spread by the members of the clinical team. Additionally, there is a requirement to safeguard medical personnel from surgical smoke aerosols emitted into the atmosphere. The efficiency of mask filtration differs. Surgical masks often filter out particles smaller than 5 mm, and masks with high filtration, filters down to 0.1 mm in size, commonly known as laser masks. Smoke contains particles as fine as 1.1 mm in about 77% of the cases (14). Despite some respiratory protection provided by high-filtration masks, virus particles are tiny than 0.1 mm. Surgical masks and high-efficiency particulate air (HEPA) respirators have the ability to defend against smoke has been extensively examined (21-25). In settings with various amounts of airborne bacteria, Lu et al investigation of filtration effectiveness involved patients wearing an N95 respirator and a disposable surgical mask (26). The N95 respirator and disposable surgical mask have filtration efficiencies of 99.93% and 91.53%, respectively. Smith et al. performed a meta-analysis to identify Six clinical and 23 surrogate exposure trials to compare the effectiveness of N95 respirators with surgical masks for the prevention of respiratory infections (26). While the majority of surgical masks consistently filter particles with a diameter of 5 micron or greater, HEPA filtration masks are excellent at filtering particles as small as 1 micron, and the likelihood of laboratory-confirmed respiratory infections and symptoms similar to the flu was considerably different between N95 respirators and surgical masks respirators. Even though surgical masks are capable of cleaning the vast majority of toxic compounds created in surgical smoke and should be worn whenever possible, HEPA masks like the N95 respirator should be taken into consideration when appropriate (15,22,27). The efficacy of the mask highly depends upon the way the surgeons, clinicians, or other members of the operatory wear it and for how long they wear it.

Ventilation

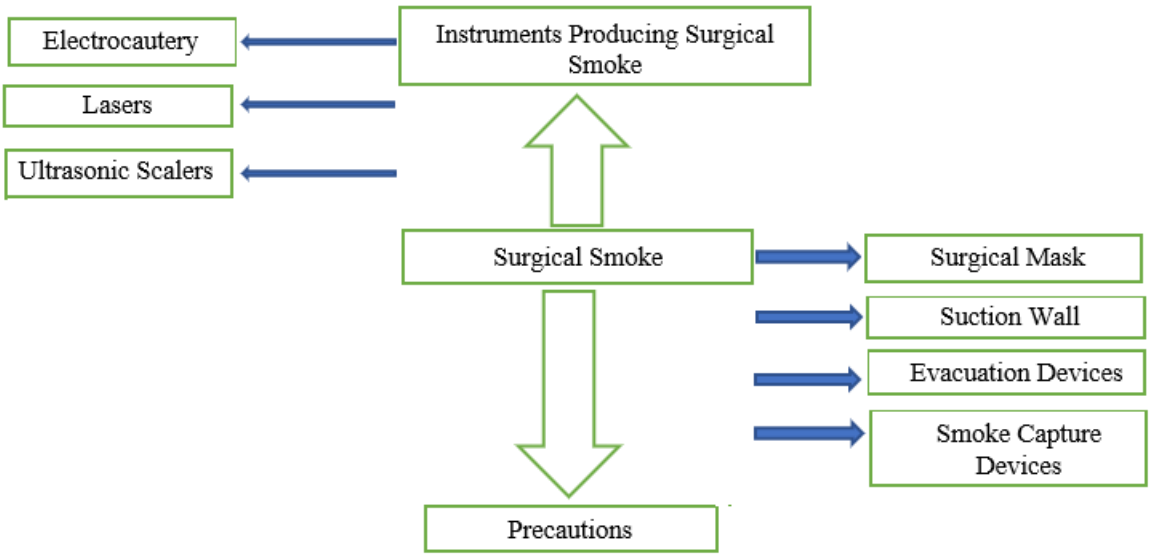
The operator's basic ventilation should be kept in good condition. Maintaining proper air evacuation from the operatory is important. As advised by the system's manufacturer, filters should be installed in the operatory's general ventilation system & periodically checked to ensure proper operation. Room air exchanges will be hampered by dirty air filters.

Capture & Evacuation of Smoke

Smoke arrest mentions to the capacity to collect smoke & direct it to an assembly location. The three elements of a successful evacuation plan ought to be: a catch mechanism that doesn't obstruct the clinician's work; a space source with sufficient pull to remove the smoke, filtering it, and enhancing environmental safety (28). Pencils used in electrosurgery are an example of a smoke-capturing instrument. The suction source's strength & capacity to generate a certain least amount of airflow are both crucial. According to Schultz et al., electrocautery smoke capture requires the lowest airflow of 0.008 to 0.010 m3/s under optimum circumstances. Hunter, on the other hand, took electrocautery smoke loss into account and suggested a minimum airflow of 0.012 to 0.017 m3/s. For operations involving intense smoke plumes, such as ablative procedures and laser hair removal, surgeons may take a higher minimum airflow into consideration (29). Suction walls are another entity that helps in smoke capture and evacuation it was one of the simplest ways to capture smoke and evacuate smoke it is basically used for procedures that produce a smaller quantity of surgical smoke and is inefficient for procedures that produce a larger quantity of surgical smoke as it usually pulls less than 5 cu ft per minute of smoke. If wall suction is employed, an in-line filter should also be used; if the smoke is not filtered with an in-line filter, the surgical team is not protected. The suction pipes and filters outside the operatory must also be kept clear for wall suction to function effectively. As an overused filter offers no protection, in-line filters must be used in accordance with the manufacturer's instructions and changed as advised. In line with basic safety precautions, in-line filters should be discarded after use (14).

Portable Smoke Evacuation System

At the moment, PSE (portable smoke evacuation) devices are the furthermost adaptable prime in the clinical room. A triple-filter configuration with an ultra-low particulate air (ULPA) filter is the furthermost efficient technique for removing smoke from space. These screens are constructed of a depth media material with a 99.9999% effectiveness rate for trapping particles as small as 0.12 microns. Only one particle out of every million will evade capture at that rate (14). Systems for portable smoke evacuation can be employed with a number of capture devices. Smoke may be captured almost at the source of its generation thanks to a small carriage unit that attaches to the ESU pencil (14). The perioperative team should plan for how much smoke will be produced throughout the procedure and select the method that is best for that procedure. However, a recent online survey of AORN members from different medical specialties and institutions across North America found that many of these facilities have not implemented best practices for protecting patients and medical personnel from the hazards of surgical smoke (30). The above-mentioned procedures are currently used in practice to evacuate surgical smoke in operatories. After taking so many steps into consideration it is often understated how dangerous surgical smoke is and how important it is to take precautions. Surgical smoke precautionary steps should be taught in early residency training so that they incorporate it into their practice.



3. Conclusion

The possible dangers of surgical smoke should be made clear to surgeons & operating room personnel. The lungs get irritated by smoke produced during surgeries and aerosols, which have mutagenicity similar to that of smoke from cigarettes. The short terms risks of smoke from surgeries should be treated on a primary basis and the long-term hazards should not be neglected. In the above article, most of the instruments that produce surgical smoke are mentioned & all the hazardous effects of the same are mentioned. Different methods to prevent the production of surgical smoke are incorporated into the operatory. Operatory personnel should take proper measures to preserve themselves & the patient against the potentially dangerous consequences of smoke from surgeries. In the above article proper measures to protect the operatory personnel are well-explained, & clinicians should acquire these above-mentioned protective practices.

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