SURGICAL SMOKE

INTRODUCTION

Personnel in operating rooms have been exposed to surgical smoke for many years, unaware that it may create certain health risks. Exposure has increased as surgical procedures have developed and the use of electro-surgery has increased.

With the development of laser surgery technology in the early 1980's the elements of surgical smoke have come under investigation.[2, 5,48,52] Research has shown that smoke generated by lasers and electro-surgical units are similar in nature. They both cause thermal destruction of tissue, which creates a smoke by-product.[1-4]

The following information discusses the dangers associated with exposure to surgical smoke and aerosol, as well as the measures that can be taken to minimize this hazard. Several methods of reducing surgical smoke will be mentioned, including smoke evacuation filters, which is one of the most effective means of eliminating surgical smoke.

HEALTH RISKS

"Surgical Smoke" is referred to as the smoke created when energy is transported to tissue cells during surgical procedures.[1] When laser or electro-surgical energy is transferred to a cell, heat is created.[1] This heat vaporizes cellular fluid, which increases the pressure inside the cell and eventually causes the cell membrane to rupture.[5-6,47] Smoke containing primarily water vapor is released. The intense heat created burns the protein and other organic matter in the cell, and causes thermal necrosis in neighboring cells.[5-6] This charring of cells, which creates smoke, not only hinders the vision of the surgical staff, but it also releases harmful contaminants, both biological and chemical, into the air.[2,5-11]

Research has not verified a direct connection between surgical smoke, aerosol, and identifiable cases of infectious disease. However, it is generally accepted that smoke and aerosol are hazardous to both patients and the surgical team, who is exposed day after day.[5,18,19,50,54] If the small particles and gases created during surgical procedures are not evacuated, they disperse into the air and can be inhaled.[10] Thus far, research data has focused on the potential health risks to operating room personnel and patients: hazardous chemicals, viruses, viable cells, and nonviable particles.[10-17]

Risks Associated with Surgical Smoke

- Airway Inflammation
- Hypoxia/dizziness
- Coughing
- Headaches
- Tearing
- Nausea/vomiting
- Hepatitis
- Asthma
- Pulmonary congestion
- Chronic bronchitis
- Carcinoma
- Emphysema
- HIV

Hazardous Chemicals

In addition to the unpleasant odor of surgical smoke, the odor is evidence of the harmful contents of the smoke.[5,6,17] The smell is a combination of chemical by-products from the burning of proteins and lipids when using laser or electro-surgical instruments.[2,8] Studies have shown that these chemicals cause headaches, irritation of the eyes, nose and throat, as well as potential long term effects.[2,8,18-19]

The absorption of carbon monoxide (CO) into the patient's blood has been the focus of research related to exposure to surgical smoke.[5,6,52,54] The formation of CO is caused by a chemical reaction between hydrogen ions produced during combustion and carbon dioxide (CO_2). Carbon monoxide easily blends with haemoglobin to form carboxyhaemoglobin (HbCO) and methemoglobin (metHb).[20] Excessive accumulations of HbCO and metHb cause hypoxic stress in healthy individuals as a result of the reduced oxygen-carrying capacity of the blood.[6,54] Furthermore, this stress can further hinder cardiovascular function in patients with cardiovascular disease.[21]

Chemicals in Surgical Smoke	
acetonitrile	hexadecanoic acid
acetylene	hydrogen cyanide
acrolein	indole
acrylonitrile	isobutene
alkyl benzenes	methane
benzaldehyde	3-methyl butenal
benzene	2-methyl furan
benzonitrile	6-methyl indole
butadiene	4-methyl phenol
butene	2 methyl propanol
3-butenenitrile	methyl pyrazine
carbon disulphide	polyaromatic hydrocarbons
carbon monoxide	phenol
creosols	propene
1-decene	polypylene
2,3 dihydro indene	2-propylene nitril
ethane	pyridine
ethene	pyrrole
ethyl benzene	styrene
ethylene	toluene
ethynyl benzene	1-undecene
formaldehyde	xylene
furfural	

Viable Viruses

In recent years, medical professionals have become more aware of the dangers of exposure to HIV,[12,13] the Human Papillomavirus,[23,27,28,53] Mycobacterium tuberculosis,[24] and the Hepatitis B virus.[26,33] Therefore, more studies have been undertaken to examine virus viability in electrocautery and laser smoke.[30] There is substantial evidence of viable virus being identified in CO_2, Er:YAG, ND:YAG laser and electrocautery smoke generated at a range of power settings.[22-30] In fact, one study showed that HIV DNA contained in laser smoke generated by a CO_2 laser remained viable for 14 days.[22] Other studies have shown a higher incidence of nasopharyngeal lesions among CO_2 laser surgeons in comparison to a control group.[28]

While research has not produced unanimous findings, the majority does provide valid concern for viable viruses in surgical smoke.[22-30]

Viable Cells

Risk of infection to operating room personnel, and concern for dissemination of cancer cells within the pneumoperitoneum leading to port-site metastasis has been a concern of researchers.[30-32] Findings in this area have not been entirely conclusive due to the number of variables that must be considered. However, many studies have shown that intact cells and blood components are aerosolized by lasers, ESUs, and ultrasonic scalpels.[26,30-32] Two studies have concluded that the cells remain viable, and that lower energy and shorter bursts are more likely to generate viable cells in the surgical smoke.[31-33]

Finally, it is believed that the liberation of cells may be caused by the manipulation of tissues with instruments during laparoscopic procedures.[35] These cells are then transported by gas flow in the pneumoperitoneum due to leakage at the ports in what has been called a chimney effect. Researchers have documented metastases at port sites remote to the removal of the cancerous tissue.[34-35]

Size of Virus	
Hepatitis C virus	0.040 µm
Hepatitis B virus	0.042 µm
Human Papillomavirus	0.045 µm
Human Immunodeficiency Virus	0.180 µm
Mycobacterium tuberculosis	0.500 µm

Nonviable Particles

The nature of minute particles found in surgical smoke can present a danger to both operating room personnel and patients, regardless of their chemical or biological make-up.[1,2,10,16,33] Particles that range in size from 0.5 to 5.0 microns are considered “lung damaging dust” because they can penetrate into the deepest regions of the lung.[36-37]

Studies have been conducted to determine the effect of surgical smoke particles on the lungs.[38] One study showed that long-term exposure deposited fine particles in the alveoli of test animals when using a CO_2 laser.[38] These particles caused congestive interstitial pneumonia, bronchiolitis and emphysema. The findings were confirmed by additional research.[10]

Although few research studies have shown surgical smoke to harm health care professionals or patients, the findings have been significant enough to cause many experts to recommend the implementation of certain devices or measures to reduce surgical smoke exposure in the operating room.[5,47,54]

MEASURES USED TO ELIMINATE SURGICAL SMOKE

Surgical Masks

Masks were originally designed to protect patients from the droplets expired by healthcare professionals working in the operating room.[39-41] Today the focus of protection has shifted to how surgical masks can be used as a safeguard for the surgical staff.

Masks have been utilized in protecting operating room personnel from the health risks associated with exposure to blood borne pathogens.[39-40] However, the standard surgical mask cannot protect the wearer from exposure to surgical smoke.[39-40] Furthermore, it is not an effective precaution against inhaling particulate matter as small as that contained in the smoke.[39-40] Standard surgical masks do not protect from possible infections from exposure to virus or bacterial contaminants, or chronic irritations of the skin or respiratory tract.[2,42-44]

High performance filtration masks, if worn correctly, provide greater protection, but are very difficult to breathe through.[1-2] Ultimately, a mask's ability to provide protection depends on the security of its' fit. Masks must conform to the face and have a tight, secure fit.[2-4]

Wall Tubing

Another common practice to remove surgical smoke is to use suction tubing and a Yankuer sucker attached to a wall mounted/mobile suction machine. A nurse holds a wand connected to the wall suction and follows as the surgeon cuts and coagulates tissue. Any liquids suctioned would go into a suction canister and the smoke would travel into the wall. Unfortunately, the power of these devices is not enough to evacuate surgical smoke properly. And, any smoke which is evacuated, will travel to the suction bottle, which frequently does not have a built-in device (filter) for the filtration of surgical smoke.

Research has shown that the smoke needs to be evacuated within one inch of its source – if any greater, only 50% will be evacuated.[1,3] Standard suction does not have high specification filters,[22] which can cause them to clog or become contaminated.

Smoke Evacuation Systems for Open Procedures

The most effective way to protect personnel and patients from the hazards of surgical smoke is to use a mechanical smoke evacuating system with a high-efficiency filter during all surgical procedures that generate smoke.[22] A smoke evacuator is basically a vacuum pump with a filtration system designed to evacuate surgical smoke, filter out essentially all of the contaminants, and return filtered air to the operating room.[45]

An efficient evacuation device must have three components: a capture device which doesn't interfere with the surgeon's activities, a vacuum source which has a strong enough suction ability to remove the smoke properly, and a filtration system that is capable of filtering the smoke and making the environment safer.[1]

The filtration system is critical.[19,45-46] It must be able to contain the volume of smoke generated, while effectively removing hazardous particles and odors. Because the amount of smoke varies significantly with different procedures, it must also be easy to use.

Smoke Evacuation System for Laparoscopic Procedures

The ClearFlow™ Smoke Evacuation System is an innovative filtration device that provides an efficient means of removing surgical smoke during laparoscopy.

ClearFlow is a passive smoke reduction system. Connected to an endoscopic cannula stopcock, it provides a controlled outflow of gas that clears smoke from the surgical site, and filters chemicals and biological pathogens from the exhausted smoke.

Features of the ClearFlow Smoke Evacuation System

- ClearFlow automatically removes and filters smoke from the surgical site through its proprietary exhaust vent without the surgical staff having to stop to make adjustments.
- ClearFlow provides for quick, harmless evacuation of surgical smoke while it effectively removes 99.999% of all virus and cells – *Retention is to 0.02 microns*.
- An activated carbon filter contained inside ClearFlow absorbs odors and gaseous hydrocarbons from surgical smoke and effectively removes them from the surgical site and the operating room.
- ClearFlow is easy to use - simply attach the rotating universal luer connector to an auxiliary cannula and clamp ClearFlow's tubing to the surgical drape. Fill the peritoneum with CO_2, open the cannula's stopcock and the rest is automatic.
- ClearFlow does not interfere with the pneumoperitoneum or the surgeon's activities.
- ClearFlow provides an efficient and cost effective solution to removing surgical smoke.

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