

LA SALLE D'OPERATION : FUMER DANS UNE ZONE NON-FUMEUR

Auteure : Sue Taylor, infirmière autorisée, CMLSO, est infirmière-enseignante et responsable de la sécurité du laser médical à l'Hôpital St Joseph's et au London Health Sciences Center. Elle siège actuellement sur le comité des normes relatives aux lasers et à l'évacuation du panache des lasers de l'Association canadienne de normalisation, est présidente désignée de la London and District periOperative Nurses Association et membre de la American Society for Laser Medicine and Surgery.

Fumer dans les lieux publics a-t-il été interdit dans votre province? En date du 3 mai 2008, la majorité des lieux de travail au Canada ont été désignés des zones non-fumeur. La protection contre la fumée secondaire est complète pour les résidents du Nunavut, Territoires du Nord-Ouest, Terre-Neuve et Labrador, Manitoba, Nouveau-Brunswick, Ontario, Québec et Nouvelle-Écosse. Cependant, en Colombie-Britannique, Saskatchewan et Île-du-Prince-Édouard, les lois protègent certains travailleurs, mais pas tous. Et pour les individus au Yukon, Alberta et compétences fédérales, il n'existe que peu ou pas du tout de protection contre la fumée secondaire au travail.¹

Tout le monde qui a vu les annonces publicitaires de Physicians for a Smoke-Free Canada à la télé est sûr de se rappeler de Heather Crowe, une serveuse non-fumeur atteinte du cancer du poumon après avoir travaillé plus de 40 ans dans des restaurants et bars pleins de fumée. Heather a fait inlassablement campagne pour les lieux de travail sans fumée. Elle a dit qu'elle voulait être la dernière personne à mourir de fumée secondaire au travail. Elle est décédée le 22 mai 2006 à 20 h. « Les preuves sont claires, » dit le docteur Atul Kapur, président de Physicians for a Smoke-Free Canada. « Tout contact avec la fumée secondaire est dangereux et la ventilation même la plus complète ne peut protéger contre les dangers qu'elle pose pour la santé. »¹

THE OR: SMOKING IN A DESIGNATED NON-SMOKING AREA

Author: Sue Taylor R.N., CMLSO, is a Nurse Educator and Certified Medical Laser Safety Officer for St Joseph's Hospital and London Health Sciences Center. She is currently sitting on the Plume Evacuation Standards and Laser Standards Committee for the Canadian Standards Association, is the President Elect for London and District periOperative Nurses Association and a Fellow of the American Society for Laser Medicine and Surgery

Has smoking in public places been banned in your province? As of May 31, 2008, most workplaces in Canada were smoke-free. There is now full protection from second-hand smoke in Nunavut, the Northwest Territories, Newfoundland and Labrador, Manitoba, New Brunswick, Ontario, Quebec and Nova Scotia. Meanwhile, in British Columbia, Saskatchewan and Prince Edward Island there are laws providing protection from second-hand smoke for some workers, but not for others, while individuals in the Yukon, Alberta and federal jurisdictions have little or no legal protection from second-hand smoke at work.¹

Anyone who has watched the T.V. commercials for Physicians for a Smoke-Free Canada, will remember Heather Crowe, a non-smoking waitress who contracted lung cancer after forty years of working in smoky bars and restaurants. Heather campaigned tirelessly for smoke-free workplaces. She had stated "I want to be the last person to die from second-hand smoke at work." Heather died at 8:00 p.m. on May 22, 2006. "The evidence is compelling," said Dr. Atul Kapur, President of Physicians for a Smoke-Free Canada. "Any exposure to second-hand tobacco smoke is hazardous and no amount of ventilation can protect people from the dangers of second-hand smoke."¹

What about OR Nurses?

While there has been a lot of movement toward the protection of the general public from the

effects of second-hand smoke, this issue has still not been adequately addressed in the operating room. Are OR staff at an increased risk due to exposure to second-hand surgical smoke?

The effects of surgical smoke include burning watery eyes (conjunctivitis), nausea, fatigue, weakness, respiratory problems, headaches, and pathogenic contamination with the risk of possible regrowth. All of these effects have the potential to negatively impact the health of O.R. staff, including an increase in sick time.

Electrosurgery units (ESUs) heat targeted cells to 100 degrees Celsius which causes the cellular membrane to rupture and creates a plume that contains, in addition to water vapour, particulate matter, gases, mutagens, carcinogens and possible viral DNA. During operative procedures additional "hot" tools, such as laser and ESUs, are being used to vaporize, coagulate and ablate tissue. In an average, one hour long, procedure smoke is produced during about 10 to 15 minutes of cautery usage. However the plume will stay in the room for as long as 20 minutes, even with air exchanges, if smoke evacuation is not used.^{2,12}

Approximately 23,000 health care workers in Canada are exposed to surgical smoke each year. Some facilities around the country do not have smoke evacuators or do not use them for various reasons that include:

1. Avoiding the constant noise being added to an already noisy area;
2. Surgical staff believing that they are not necessary or not recognizing the issue as a safety concern;¹²
3. The false belief that masks provide adequate protection from the plume; and
4. The cost of the disposables. (filters, active electrodes evacuation tubing) Should this specify which part is disposable?

Smoke generated by ESUs was not, in the past, recognized as an inhalation hazard. A lack of understanding, education, research, suitable evacuation methods, and poor compliance by physicians and nursing staff contributed to the problem. Laser use, since the 1980s, has resulted in an increased knowledge about

inhalation hazards. Early on the dangers of laser plume were recognized and, as a result, smoke evacuation methods were developed and used. Studies have shown that laser and ESU plume have similar content and both are hazardous. A study by Tomita (1989) showed that laser plume posed the same health hazard as smoking three cigarettes. The temperature generated by lasers is higher than that generated by cauteries and, as a result, they cause more cell vaporization.

ESUs cause vaporization at a lower temperature and are used 15 to 20 times more frequently than lasers. ESU plume was shown to cause a health hazard equivalent to smoking six cigarettes.³ Aerosolized contaminants are produced in both the cut and coagulation modes when ESUs are used. Hazards fall into two categories: biological and chemical. The potentially toxic chemicals in surgical smoke and aerosol include proven toxins, mutagens, carcinogens, and allergens while the potentially harmful biological components include infectious bacteria and viruses (either intact or fragmented).

Who is at risk?

Surgical smoke is hazardous to the entire surgical team that is exposed to it. This includes nurses, anaesthesia providers, patients and surgeons. While surgeons may feel that they have the greatest exposure to the plume because of their proximity to the surgical site, nurses are exposed on a more consistent basis given that they are in the OR five days a week. Ongoing exposure is not good for anyone!

Twenty seven different chemicals have been isolated in surgical plume. While surgical smoke comprises 95% water vapour the remaining 5% can be hazardous to the health of OR staff. This portion poses more than just an inhalation risk. As an example, soft contact lenses are porous and are therefore prone to absorbing hazardous airborne chemicals including those that have been identified in surgical plume.

The actual number of particles present in surgical smoke and aerosol can vary depending on the type of surgery and its duration. Generally the quantity of particles ranges from

SMOKE (cont.)

1,000,000 to 1,000,000,000. In a British study Walker and Brian (1990) found viable bacteria present in laser plume regardless of the power densities and duration of use. It was also noted that *Staphylococcus Aureus* was more resistant to the lasing effects than was *Escherichia Coli*.⁴

Baggish and coworkers (1991) studied the effects of using carbon dioxide laser plume on the lungs of rats. In rat lungs exposed to laser plume for various periods of time, they found congestive interstitial pneumonia, bronchiolitis and emphysema.⁵ The noxious odours from surgical smoke are caused by the chemical by-products that are emitted when a hot tool is used to vaporize, cut, ablate, excise, or coagulate tissue.

Various toxic chemical byproducts have been identified in surgical smoke (see Table 1). It is estimated that over 100 more compounds, found within surgical smoke, have yet to be identified.^{14,15} In industry many of these chemical components, if isolated, are required to be evacuated from the workplace environment.

Table 1: Chemical Compounds found in Surgical Plume

Acrolein	Free radicals
Acetonitrile	Furfural (aldehyde)
Acrylonitrile	Hexadecanoic acid
Acetylene	Hydrogen cyanide
Alkyl benzenes	Isobutene
Benzaldehyde	Methane
Benzene	3-Methyl butenal (aldehyde)
Benzonitrile	6-Methyl indole (amine)
Butadiene	4-Methyl phenol
Butene	2-Methyl propanol (aldehyde)
3-Buteneitrile	Methyl pyrazine
Carbon monoxide	Phenol
Creosols	Polycyclic aromatic hydrocarbons
1-Decene(Hydrocarbon)	Propene
2,3-Dihydro indene (Hydrocarbon)	2-Propylene nitrile
Ethane	Pyridene
Ethene	Pyrrrole (amine)
Ethylene	Styrene
Ethyl benzene	Toluene
Ethynyl benzene	1-Undecene (Hydrocarbons)
Formaldehyde	Xylene

Toluene is an industrial solvent that is irritating to the eyes, nose, and respiratory tract. Chronic poisoning has resulted in anemia, leukopenia, and bone marrow hyperplasia. Chronic inhalation during pregnancy has been associated with teratogenic effects on the fetus.

Acrolein is highly toxic if inhaled or ingested. Its vapours irritate the nose and throat and can severely irritate the eyes, causing reddening of the eyelids, tearing and swelling.

Formaldehyde: This embalming fluid is carcinogenic, very toxic, and corrosive to skin and mucous membranes. Gas and vapours are irritating at very low levels. It is one of the most common causes of occupational skin disease. Excessive or repeated exposure may cause kidney damage.

Benzene is an industrial degreasing agent that increases the risk of leukemia with prolonged low-level exposure. Prolonged skin contact or excessive inhalation may cause irritation of the eyes, nose, and respiratory tract, euphoria, nausea, drowsiness, headaches, dizziness or intoxication.

Hydrogen Cyanide (HCN) is also found in rat poison. Inhalation of lesser concentrations can cause headache, vertigo, nausea and vomiting. HCN levels of 100 ppm have been measured at lasing sites. This level is ten times higher than recommended limits.

Methylmethacrylate: OR personnel are exposed to additional hazards when using the laser to vaporize the methylmethacrylate used in orthopedic implants. The harmful byproducts emitted in these procedures include cyanide gas, carbon particles and fluorocarbons, all of which are dangerous if inhaled.

PARTICULATE SIZE: Studies^{6,7} have shown that, while surgical masks only filter 5 mm particles, 77% of particulate matter is less than 1.1mm in size. This is the most dangerous particle size, as it is the optimal size to be deposited in the lower

Continued on Page 12

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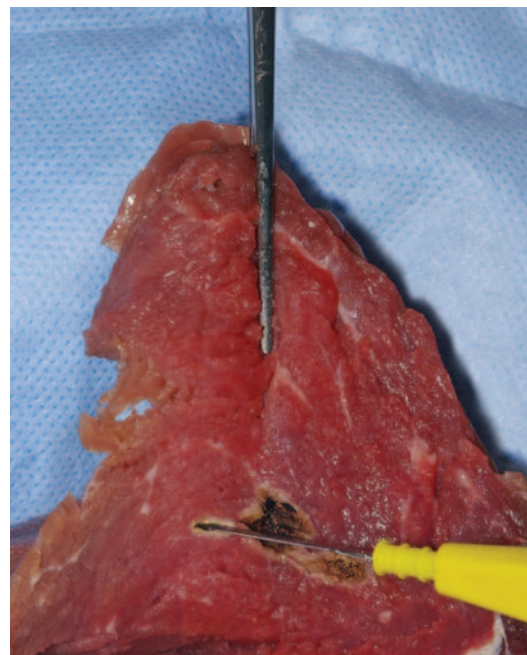


SMOKE (cont.)

respiratory tract. Upon inhalation the plume can be deposited anywhere along the respiratory tract. Particulates and debris can be caught by the nasal cilia or may attach to the mucous membrane and cause minor irritation. The toxic components of the plume may be absorbed by the mucus membrane anywhere along the respiratory system resulting in rhinitis, bronchitis, nausea, fatigue, hallucinations or headaches. All of these studies noted that this particulate matter should not be inhaled.

Studies have shown that when bacteria have been lasered, viable bacteria could be found after culture and that viral D.N.A. from human papillomavirus (HPV) and Human Immunodeficiency Virus (HIV) were detected in laser and ESU plume. Mycobacteria have also been isolated. Studies have shown conclusively that there was no HPV cultured from a surgeon's nasopharynx, ears and eyelids if smoke evacuators and laser masks were used.^{4,8,9}

Patient exposure can be an issue as well, as the harmful constituents of surgical smoke can be absorbed by skin and mucus membranes. During laparoscopic surgery the plume



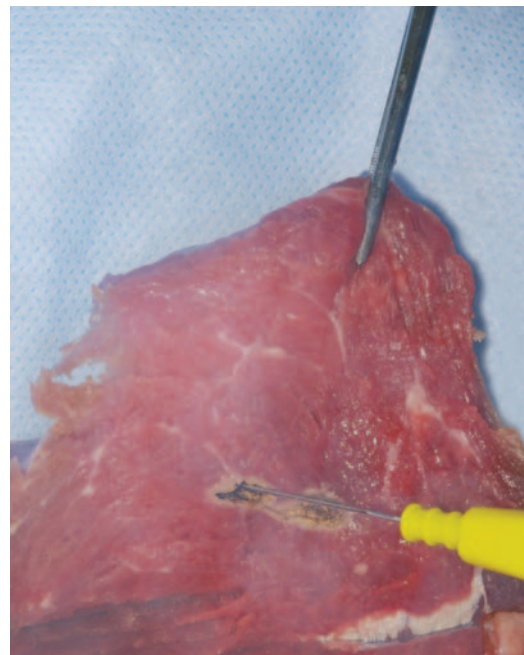
By/Par: J. Porteous

Electrosurgery being used on tissue, no smoke has yet been generated.

produced within the enclosed space will remain and be absorbed by the tissues unless it is removed. The pneumoperitoneum needed for laparoscopic surgery can increase the rate of absorption. Methemoglobin is an oxidative part of hemoglobin and is unable to carry oxygen. This element inhibits the normal ability of hemoglobin to off load oxygen to the tissues. In procedures involving one of the "hot" tools patients had a post-op level of methemoglobin that was triple the level found prior to the surgery.¹⁰ Carbon monoxide is produced by electrosurgery of the tissue. Carbon dioxide used for insufflation is present in the peritoneal cavity at mean concentrations of 345 ppm. At the end of surgery the patients' mean concentration of methemoglobin was 475 ppm.

PROTECTION METHODS:

There are various methods used to evacuate and protect O.R. staff from the surgical plume. These include wall suction, masks and dedicated smoke evacuators. Wall suction has been used for years to evacuate smoke. Problems arise when the smoke condenses inside the suction pipes inside the walls and narrow



By/Par: J. Porteous

Smoke resulting from the electrical cutting current generated by the hand-piece.

SMOKE (cont.)

the diameter thereby decreasing the suction capabilities not to mention what might be growing inside the pipes. The typical wall suction only pulls between 3 and 5 cubic feet per minute. However efficient smoke evacuation requires a vacuum source that pulls much more. Airborne particles and organisms evacuated from the surgical site can be deposited into the central vacuum system where they can multiply. This can result in a "sick O.R." and even greater potential hazards.

Surgical masks are designed to protect patients from airborne droplets from operating room personnel. Protection provided by a mask depends on both the filtration efficiency and the leakage between the open spaces and the wearers face. Flat masks have been proven to work more efficiently than cone shaped masks. Masks are reasonably efficient at filtering particles between the sizes of 0.3 to 1mm. To effectively address the surgical smoke issue a mask would have to be designed to filter particles from less than 0.1mm. In addition surgical masks only filter particulates, not chemicals.⁹

Particulate sizes:

Hepatitis B virus, 0.042 μm
Human Immunodeficiency Virus, 0.180 μm
Human Papilloma Virus, 0.045 μm
Mycobacterium tuberculosis, 0.500 μm

Smoke Evacuators

Smoke evacuators, initially developed to evacuate laser plume, are quite effective at removing both odour and particulate matter. They transport surgical plume away from the operative field via a capture device, a vacuum and a filtration system. Variable flow settings are an asset on any smoke evacuator, so that high settings can be used for regular cases and low settings for laparoscopic procedures. The best vacuum tubing is a high grade corrugated tubing that will not collapse or kink during use. An activation device is a great safety tool as it detects electrical current leakage. When such a device is attached to the ESU pencil cord staff does not need to worry about the system.

Filtration Systems

The plume evacuator filtration system is composed of a pre-filter, a high-efficiency filter, and an activated-charcoal filter. There are many different types of filters available for use with a plume evacuation system.

Prefilters

Prefilters, made of sponge or wire grating, are used to capture objects (e.g., cotton), fluid, or gross particulates that can be accidentally sucked into the airstream and subsequently damage the high-efficiency filter or the evacuator pump.

A High Efficiency Particulate Air (HEPA) filter captures 99.97% of particles 0.3 μm in diameter and only three particles out of 10,000 pass through the filter.

An Ultra Low Penetration Air (ULPA) filter is designed to capture very small particles and organisms. It captures 99.999% of particles 0.12 μm in diameter so that only one particle out of 100,000 passes through. Research has shown that pathogens such as HIV, HPV, and HBV particles are found attached to droplet nuclei, and that the total size of the particle is significantly larger than the 0.1- μm particles that an ULPA filter is designed to capture.

The state-of-the-art filtering system is referred to as a Very Large Scale Integrated (VLSI) filter. It is essentially an ULPA filter with the highest efficiency rating. VLSI filters capture 99.9999% of latex spheres 0.12 μm in diameter. Only 1 particle out of 1,000,000 passes through.¹³

High Efficiency Filters

A membrane filter efficiently captures particles larger than its pore size (e.g., a 0.5- μm filter will block a 10- μm particle). Membrane filters are thin, highly efficient, and have well defined filtration characteristics. They generally have higher flow resistance and a lower particle-loading capacity (the number of particles per

Continued on Page 21

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SMOKE (cont.)

unit of area that can be captured before the filter's performance is affected) than depth-media filters. Because of their much lower flow resistance, higher particle capture capacity, and longer life, most smoke evacuators use depth-media filters. A depth media filter consists of randomly oriented glass or polypropylene fibers. The open spaces between the densely packed fibers are much larger than the particles to be captured, so filtering action results when the particles come in contact with, and adhere to, the fibers through the forces of inertial impaction, electrostatic attraction, and diffusion.

Activated Charcoal Filters

Activated charcoal filters absorb odours and gaseous hydrocarbons from the waste exhaust. Odour-control efficiency is related to the filter's CTC (carbon tetrachloride) rating. The CTC rating is the percent by weight of CTC vapour the charcoal can absorb. For example, 1 pound of CTC-60 charcoal can absorb up to 60% of its weight or 0.6 pounds of CTC vapor.

Activated charcoal is a carbon-based compound that is baked at high temperatures without the presence of oxygen. This process "activates" the charcoal by removing the organic compounds and leaving only the carbon matrix behind. Through this process, the carbon granules become full of active sites where organic molecules may be captured without changing the carbon structure. There are different types of carbon used for these filters. Wood, coconut and coal grade carbons are used, with coconut being the most commonly used in smoke evacuation filters. This type of activated charcoal readily absorbs water vapour as well as organic molecules. Research has confirmed the effectiveness of charcoal filters on tests with rats exposed to laser plume. When a charcoal filter was used the rats were shown to suffer much less lung damage. When, however, an ULPA filter was added there was no lung damage whatsoever.¹¹ Some filters are impregnated with an antimicrobial agent to inhibit the growth and reproduction of microorganisms. These agents work through poisoning, oxygen deprivation, interruption of DNA replication and cell division, cell wall disruption, or by interfering with oxidative phosphorylation.

Additional Aspects of the System:

Air fresheners are used to scent the air exhausted from the system. They take an unwanted odour and replace it with another odour or use a heavier odour to mask the presence of the first odour. If the OR team is able to detect the odour, either during or after surgery, it usually means the smoke evacuator is not working optimally.

The ability of the suction to effectively remove the plume is a direct result of the volume of air being removed from the surgical site. The best vacuum motor creates a vortex that overcomes the particles momentum by changing their direction, so they are drawn through the system.

A control panel typically includes an on/off switch, flow control mechanism, and a delay control mechanism. Some have specific high/low flow switches for laparoscopic or regular usage. Some evacuators have a remote device that activates the machine in conjunction with the laser or ESU.

Centralized vacuum systems, rather than ordinary wall systems, can be incorporated into an articulating arm which is attached to the service column. Disposal tubing is attached to the arm and pulled over the surgical site where the plume is sucked into a centrally maintained filter system. This system can be readily incorporated in to a new surgical facility. There are some of the same concerns with the centralized system as there would be with the use of an ordinary wall system.

ADVOCACY:

There are many groups that have issued statements about the risks of surgical plume: The Operating Room Nurses Association of Canada (ORNAC), Canadian Standards Association (C.S.A.), Occupational Safety and Health Administration (OSHA), The National Institute for Occupational Safety and Health (NIOSH), and The Association of Perioperative Nurses (AORN). A web search will list over one million articles on this subject.

SMOKE (cont.)

OR nurses spend a great deal of time acting as an advocate for the unconscious patient. Often the patient's needs are put well ahead of the nurse's. It is time to start advocating, for the sake of all the OR staff, on this health issue. We can educate ourselves about the known risks, talk to management about a cleaner work environment, talk to your facility Occupational Health Unit, our peers, professional associations, unions and surgeons. It is also important to talk to the staff in other areas where cautery is used, such as the outpatient and endoscopy clinics. As this issue is discussed in broader forums its hazards and problems are more likely to be addressed.

ORNAC Standards pertaining to this article can be found in the Operating Room Nurses Association of Canada (2007) (ORNAC). *Recommended Standards, Guidelines, and Position Statements for Perioperative Registered Nursing Practice* (8th edition). In Module 3, p. 69, Standard 6.2.9 Plume (Laser smoke), and Module 3, p. 76-77, Standard 6.5 Smoke Evacuators

Les normes professionnelles de l'AIISOC relatives à cet article sont citées dans le document suivant édité par l'Association des infirmières et infirmiers de salle d'opération du Canada (2007) : *Normes de pratique recommandées, lignes directrices et énoncés de position pour la pratique en soins infirmiers périopératoires* (8^e édition) Module 3, page 69. Norme 6.2.9 (Vapeur de laser), et Module 3, pages 76 à 77, Norme 6.5 (Évacuateur de fumée).

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