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Potential Hazards from Electrosurgery Plume

Recommendations for Surgical Smoke Evacuation

By Marlys Hoglan, RN, CNOR

Most hospitals today are "non smoking" hospitals. Where is the one place in the hospital that smoking occurs on a daily basis and nobody objects? That's right, the operating room, and who is breathing it? The perioperative nursing staff, anesthesia personnel, surgeons, and the patient. What you see in the OR every day is the steam and what you are breathing is the vaporized tissue.

The cancer society took a long time to convince us that cigarette smoke caused lung cancer. Think about the years and years of research that went into their findings before they said "yes, we have proven it, cigarette smoking is hazardous to your health." Perhaps research will eventually tell us that breathing electrosurgery (ES) smoke is also hazardous to our health.

Laser Smoke Evacuation

Is there any difference between the smoke plume that is created from electrosurgery and that created from the use of a laser? No, there is no difference. The thermal action on the tissue is the same regardless of the energy source that is used. It was always recommended that we evacuate the smoke generated from laser usage and recent research is supporting the fact that we should be removing all surgical smoke, regardless of the energy source that creates the smoke.

The Emergency Care Research Institute (ECRI) is an agency in the U.S. that monitors medical devices. It is an independent agency that is not affiliated with any manufacturer of surgical products. They investigate health care issues and make recommendations that relate to safety for our patients and employees. Most of your BioMeds or clinical engineers are familiar with ECRI publications. The ECRI has stated that

they are concerned that we have overlooked the fact that electrosurgery smoke is the same as laser smoke and this could be hazardous to our health.

Spectral Content of Surgical Smoke

What is the potential risk of exposure? What are the recommendations? How can we protect ourselves? Is evacuation the answer, and if so, what components should the system contain to provide the kind of filtration efficiency required to make it effective.

Contents of Surgical Smoke

The smoke created during electrosurgery contains three primary components.

The first is particulate matter which consists of the carbonized tissue, blood, and potentially infectious viruses and bacteria.

The second product is steam, and of course, that is what you see. If your hand is placed over the steam, you will see moisture on your glove. Since cells are

Author

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This article is an edited version of her taped presentation to the 14th National Conference of the Operating Room Nurses Association of Canada's in Vancouver, B.C. in May, 1995.

primarily water, the electrosurgery releases

The third component is potentially hazardous these to be carcinogenic benzene, formaldehyde, aromatic hydrocarbons PAH is the same in surgical barbecue. It smells like a neighbors yard especially not good for us to breathe

"Carbonized tissue is the toxic component of surgical smoke. These are all carcinogenic."

A perioperative nurse needs these educational

"You know, I had a case of surgical smoke in the operating room. I had some allergic reactions when I was tested on a case that is allergic response to the smoke."

The formaldehyde is since it is one of the

Toluene is also an issue. Months ago in St. Louis containing toluene in the downtown area where the highway was closed and evacuated until the people who were in the area to breathe and their lungs burned." We know that formaldehyde is a carcinogen.

Universal Precautions

One of the most disturbing, is that formaldehyde is from laser smoke (ECRI 1991). Remember that

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primarily water, the cellular explosion caused by electrosurgery releases the steam.

The third component is the various toxins or the potentially hazardous chemicals. Research has shown these to be carcinogenic. The toxins include acrolein, benzene, formaldehyde, toluene, and polycyclic aromatic hydrocarbons (PAH) (Sawchuk, 1989). The PAH is the same in surgical smoke and your backyard barbecue. It smells wonderful coming from your neighbors yard especially if you are hungry, but it is not good for us to breath this smoke.

“Carbonized tissue, the toxic gases, the possible microorganisms are all contained in surgical smoke.”

A perioperative nurse came up to me following one of these educational programs and said: “

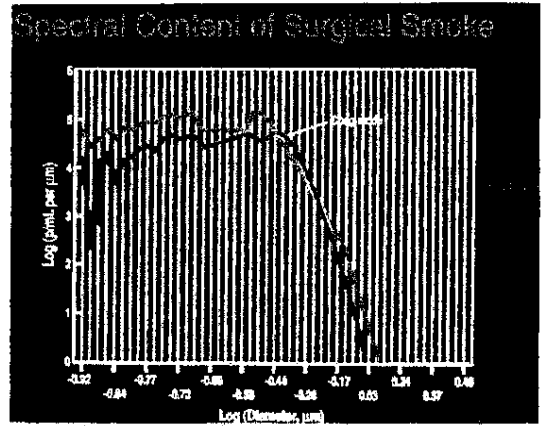
“You know, I have an allergic reaction to surgical smoke. Since I went to work in the operating room two or three years ago, I have had some respiratory problems and when I was tested, they discovered that I am allergic to formaldehyde. Every time I scrub on a case that is real smokey I get this same allergic response. Might it be the formaldehyde in the smoke causing it?”

The formaldehyde could very well be the irritant, since it is one of the chemicals in surgical smoke.

Toluene is also an irritant to us. For example, a few months ago in St. Louis, Missouri, a railroad car containing toluene was derailed and turned over in the downtown area where major highways merge. The highway was closed to traffic and a six block area was evacuated until the spill could be cleaned up. The people who were in the area stated that it was “difficult to breath and their eyes and mucous membranes burned.” We know that it is an irritant, and it is also a carcinogen.

Universal Precautions

One of the research findings that I find disturbing, is that HIV proviral DNA was cultured from laser smoke for at least 14 days (Baggish, 1991). Remember that there is very little difference



Printed with Permission from ECRI's evaluation on "Laser Smoke Evacuators", from *Health Devices*, Vol. 19, No. 1, Jan., 1990.

between laser and electrosurgical smoke. This points out the fact that we should be using universal precautions when handling the equipment used to evacuate the surgical smoke.

I remember using the wall suction to evacuate smoke, especially on an augmentation mammoplasty. As the pocket was created for the implant, a lot of smoke was produced. The Yankauer suction tip was placed into the pocket and the smoke was evacuated into the wall vacuum system. We would have used universal precautions for the tubing, because it was the same tubing that was used for suctioning blood and other fluids, but we were not concerned that the smoke was entering the wall vacuum. This smoke was going into the filter of the wall vacuum system. Who is changing those filters? Probably your maintenance or housekeeping staff. Are they using Universal Precautions when they change the filters? I would doubt it. The practice of using hospital vacuum lines is not recommended for two reasons according to ECRI. (1) the particulate matter in the smoke can deteriorate hospital vacuum systems, and (2) the flow generated by wall suction may not be strong enough to capture the smoke. We have had maintenance reports that filters are needing to be changed more frequently than they used to, and they wonder why this is occurring.

Another research study (Gatti, 1992) showed that the smoke generated from the use of electrosurgery during reduction mammoplasty procedures was found to be mutagenic. This could prove to have far reaching effects.

I equate the smoke issue to an issue that concerned us many years ago and that was anesthesia waste gases. Perioperative nurses said “We don't think we

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should be breathing this waste gas, we get headaches, and we don't feel good." The reply was often "You nurses are always complaining about something." Well, after enough documentation and research, it was discovered that this waste gas should be evacuated. I believe this will happen with surgical smoke.

Why have we not been concerned about this before now? I think there are at least a couple of reasons. One is that we didn't use electrosurgery on almost every case as we do now. Today it is an automatic part of the preoperative preparation for surgery to place the dispersive electrode (grounding pad) on the patient and have an electrosurgical (ESU) unit in the room. Nearly all surgeons use the ESU. We estimate 90% of all surgical procedures use electrosurgery.

Do you remember when we had "dirty cases" and the only "dirty cases" were those that had visible pus? Many of us in the operating room said, "wait a minute, this doesn't make good sense to us, we think we should treat all cases alike, because there might be harmful organisms we can't see. The reply often was "oh no, we'll only treat the cases we know are "dirty". Well, we know in the U.S. that the Center for Disease Control (CDC) and AORN have said we must use universal precautions on all invasive procedures. Many years ago we didn't have some of the viruses we have today and there may be additional viruses in the future. This means precautions against the risk of exposure to infectious materials must be taken by all health care workers.

We know surgical smoke is not sterile. Proviral DNA and carcinogens have been identified in the smoke plume, but we have not seen any research, as yet, that directly documents this plume has caused any infections. In this situation should we be proactive or reactive? Do you want to wait until somebody proves there is a problem and then wish we had been evacuating the smoke a long time ago?

What about the smoke generated during a transurethral resection of the prostate (TURP)? I have been told that if you can smell the plume, it is present. We all know how it smells when a TURP is performed. The plume is contained in liquid in this procedure, so whether that liquid is filtering out the particles and carcinogens, I don't know. Perhaps this would be a good research project.

Live Viral DNA is Present in Smoke

The results obtained and reported by Sawchuk et al, indicated that although this viral DNA was present in

the vapors when treating infectious Papillomavirus, they did not determine if it was infectious. What about the bacteria that is present in plume? I have not seen any research papers on that particular issue.

The chronic irritation to the skin, lungs, and mucous membranes due to inhaling the surgical smoke has been reported. It has also been reported that smoke is absorbed by soft contact lenses. Has anyone had a problem with their eyes as a result of this absorption? Not that I know about.

Who is absorbing most of the smoke? The scrub person, surgeon, and assistant. Most surgeons are not very concerned about the smoke issue, however. This may be because they do their procedure and then they leave. That is not the case for the OR personnel because they stay and do cases for their entire shift which may be 8, 10, or 12 hours depending on the schedule and call time required. Perioperative nurses, anesthesiologists, and anesthesiologists are breathing this smoke day in and day out. Surgeons, however may operate only two or three days a week and for just a few hours on those days, so this may explain their indifference with this issue.

Plastic Surgeons Concerned

We have experienced some concern from plastic surgeons who perform reduction mammoplasties. Many of the other surgeons consider the use of a smoke evacuator as bothersome. They have heard that there are carcinogens present, but they don't want an extra hand in their way trying to evacuate the smoke during the procedure.

One of the functions of my job has been to assist with physician Large Loop Excision of the Transformation Zone (LLETZ) seminars and workshops. I know some of the gynecologists in Canada are doing this procedure, perhaps not in the hospitals, but in the clinics, outpatient centers, or offices. They can remove cervical tissue to treat cervicitis, dysplasia, and carcinoma in situ with this procedure. The removal is done with a wire loop and electrosurgery. It works extremely well and is very quick, but the smoke generated is overwhelming. I did one workshop when we had twelve generators set up and approximately 200 surgeons practicing this procedure on beef tongue. Beef tongue is used because it responds much like cervical tissue. The smell in the room was dreadful. Even though we were trying to evacuate the smoke, we were unable to capture all of it. This workshop was a few years ago and there were not as many good smoke

evacuators on the clothes reeked with cleaned before I came home. My membranes of my nose know that smoke

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evacuators on the market then as there are now. My clothes reeked with the putrid odor, so I had them cleaned before I could pack them in the suitcase to come home. My eyes watered and the mucous membranes of my nose and throat burned and itched. I know that smoke was a severe irritant.

Recommendations: Evacuate Laser and Electrosurgical Smoke

What are the current recommendations regarding surgical smoke? The National Institute for Occupational Safety and Health (NIOSH) in the U.S. has determined that there is a potential hazard from exposure to smoke generated by the use of electrocautery. NIOSH does research. It is, however, the Occupational Safety and Health Administration (OSHA) that mandate job safety and health standards and enforce them. So far, they have not made smoke evacuation a mandate, but since NIOSH has recommended evacuation of laser smoke, it only makes good sense that electrosurgery smoke should also be evacuated.

After one of these educational programs was presented to a group of perioperative nurses, one of the OR managers who attended the program called OSHA and asked what their policy was concerning electrosurgery smoke. Their reply was that they hadn't made one, but they would send someone to her facility to check it out. They sent an inspector into her hospital and they are waiting for the report. She is extremely distressed, because she feels that she reported her own facility and that was not her intention at all, she simply wanted some information. If they are cited they will be charged a very large fine and this manager will be blamed. Needless to say she is very concerned and I would feel the same way in her position.

AORN Recommended Practice

In the 1994 AORN Recommended Practices for Electrosurgery (RPE) it is recommended that patients and perioperative personnel should be protected from inhaling the smoke generated during electrosurgery. The Recommended Practice Committee studies issues very carefully before they publish their recommendations. This RP has a very lengthy bibliography to support their recommendations.

Reducing Exposure to Smoke

What methods can we use to reduce our exposure to the ES smoke? We could try to reduce the production of smoke, but how are we going to do that? I don't think we want to tell our surgeons they can't use electrosurgery anymore. Well then, what can we do to minimize the amount of smoke plume we are forced to inhale? The obvious answer is to evacuate the plume through a filter system that will remove the hazardous materials.

Masks as Protection From Plume

Do the masks we wear provide protection from potentially harmful plume? Our standard masks filter up to 0.5 microns and viruses are smaller than this, so they have the ability to pass through the mask. When doing laser cases, we often wear a high filtration mask. They are very thick and make breathing difficult. They only filter up to 0.1 microns and most of the potentially harmful particles are smaller than 0.1 microns, so they really aren't doing much good at all. One day I was circulating for a laser case that produced a major amount of smoke and lasted for hours. The smell was penetrating my mask, so I tried putting on two of the heavy duty masks. I don't recommend trying this! I could not breath at all, it was as if someone had placed a plastic bag on my head.

A Capture Device is Needed

To effectively evacuate plume we need three components in the evacuation system. There must be a capture device, a vacuum source, and an efficient filter. I will address each of these components separately.

The capture device must be large enough and close enough to the surgical site to capture the volume of smoke plume that is being generated. Some of the research states that it will be most effective if it is placed within six inches of the operative site. Will the surgeons like this? Probably not. Who is going to hold the capture device? Our scrub person can't grow a third arm and we rarely have additional staff to provide another person at the sterile field. Even if we can provide someone to hold the device, many surgeons feel that it is in their way. The most logical solution is to have the evacuation occur on the ES pencil so that it can evacuate the smoke as it is generated. A second

option is to use a capture device that has a large diameter tubing. It can be positioned so that when it is clipped to the surgical drape, it is in a stable position throughout the procedure. The disadvantage of this is that it may not be within six inches of the surgical site.

Vacuum Systems

The vacuum source needs to be portable and easily moved. Nobody told me when I went to nursing school how much time I would spend moving furniture and equipment. Since we will probably be moving the evacuator from room to room it must be easy to transport.

If you use your wall suction, it may interfere with other vacuum requirements such as the suction power required at the surgical site or the suction the anesthesiologist may need to have available.

Wall suction traditionally removes three cubic feet per minute (3 CFM) and we have been told that proper removal of the plume requires 50 CFM. A separate smoke evacuation unit will be the only way to obtain 50 CFM.

There are many smoke evacuation units available, so to obtain the appropriate system for your facility, the OR staff will need to do some evaluations. Establish the criteria you will use to select your evacuation unit. It may be helpful to use the criteria suggested for selection of a smoke evacuator in the AORN RP for Laser Safety in the Practice Setting.

Filter requirement

A triple filter system should be used in an evacuation unit. The first portion is a prefilter. The prefilter is a single use, disposable filter. This pre-filter is disposed of using Universal Precautions at the conclusion of the procedure. The purpose of the pre-filter is to collect the largest particles and the moisture from the steam. We have observed that this pre-filter resembles a cigarette filter when it is removed. It is often a dirty yellow color.

The second portion of the filter should be an Ultra Low Penetration Air (ULPA) filter. High Efficiency Particulate Air (HEPA) filters are being used as in line filters when wall suction is being used. The HEPA filter is not as efficient as the ULPA filter. Evacuation

units should have ULPA filters. An ULPA filter removes 99.9999% or 1 in 1,000,000 particles get through the filter.

The third portion of the filter is charcoal. The charcoal removes the odor and absorbs the gas.

Noise Level of evacuators

The noise level is one of the major objections by surgeons. These are vacuums and they will make some noise. Have you ever heard a silent vacuum? As you prepare to evaluate smoke evacuators, you should consider doing side by side evaluations in the same circumstances. The noise level will sound entirely different in the lounge than it will in an operating room with all of the other noises. Assess them in the same way, side-by-side, so your ears don't trick you.

Endosurgical Smoke Considerations

When doing laparoscopic procedures, we often need to remove the smoke because it interferes with visibility for the surgeon. The smoke is created by the use of either a laser or electrosurgery in the peritoneal cavity. According to Beebe, et al a hazard for the patient may be created when the carbon dioxide and surgical smoke are mixed. This mixture becomes carbon monoxide. Dr. Ott from Macon, Georgia has studied the effect on the physiology of patients when this occurs during laparoscopic procedures. An elevation in the methemoglobin occurs in these patients. When methemoglobin is formed by the red blood cells, it renders the hemoglobin incapable of carrying oxygen. When I have discussed this with some anesthesiologists, they have said that this may be the reason patients take longer to wake up after a prolonged laparoscopic case. These patients also complain of more headaches and nausea, which are early symptoms of carbon monoxide poisoning.

This information suggests that we should be evacuating the plume from the abdominal cavity through a smoke evacuator periodically during the procedure. We should definitely evacuate the pneumoperitoneum at the conclusion of the procedure through a smoke evacuation unit rather than allowing the aerosol containing hazardous particles to pollute the air we are breathing.

Nursing Considerations

As I stated earlier, selecting a smoke evacuator to you about the preferences you want to have is the filter life even use on a smokey case when minimal smoke cost per procedure.

Ensure that they are available to use for all types of smoke. Test them to see if it will effectively remove the smoke selected should have.

Examples of High Efficiency Particulate Air (HEPA) Smoke Procedures

- Modified Mastectomy
- Reduction Mastectomy
- Total Joint Replacement
- Spinal Reconstruction
- Liver Resection
- Abdominal Incision
- LLETZ / Cervical
- Condylomata
- Radical Prostatectomy
- Thoracotomy

Conclusion

Not enough research has been done with the ammunition available to make this a priority in the OR.

One research project would be to track the incidence of OR infections of the OR attributed to OR smoke. Small amounts of surgical smoke, small amounts. I am not sure how to account for this. It could be a very important project.

If this data demonstrates high amounts of smoke exposure, then those exposed should support the need for more research in the U.S. did his findings, installed however, does not support the project.

The available research probably should evaluate the use of universal precautions and tubing. Our tra-

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Key Terms

Adsorption: The adhesion of gas or liquid molecules to the surface of a solid (Van der Waals adsorption). As applied to activated carbon, the "surface" is that of the interior pore structure, and in magnitude is in the order of six million square feet per pound of charcoal.

Airborne Contaminants: A substance carried by or through the air that contaminates (infects, pollutes, defiles) another substance.

Bronchitis: Inflammation of the bronchial tubes due to exposure to cold, to the breathing of irritant substances and to acute general diseases.

Carcinogen: Any cancer-producing substance.

CFM: Cubic Feet per Minute/ volumetric air flow.

Charcoal Filter: This filter is for odor and gas adsorption. It may or may not be combined with a depth media filter for capture of gross particulate. Odor-control efficiency is related to the CTC (Carbon Tetrachloride) rating. The CTC rating is the percent by weight of carbon tetrachloride vapor the charcoal can adsorb—1.0 lb. of CTC-60 charcoal can adsorb up to 60% of its weight or 0.6 lb. of carbon tetrachloride vapor.

Dimensions: 1 meter = 1³ millimeters (mm)
= 10³ micrometers (microns, μm)
= 10⁹ nanometers (nm)
= 10¹⁰ angstroms (A)

DNA: See Nucleic acid.

Filtration: To remove or separate solid particles, gases, etc. from a liquid or air by means of a filter.

Flow Velocity: This is the measure of the speed of air flow. It is a function of the diameter of the tubing or orifice and the cfm. Intake velocity at the nozzle orifice is the most important parameter in relation to smoke plume capture.

HEPA Filter: High Efficiency Particulate Air filters are used as particulate filters in smoke evacuators. The industry minimum standard, as defined by the Institute of Environmental Sciences (I.E.S.) for HEPA filters, is

99.97% efficiency in capturing particles of 0.3 micron and larger. The efficiency percentage is required for the rating to be meaningful.

Micron: A unit of length equal to one-thousandth of a millimeter, or one-millionth of a meter. Important particle sizes include:

Hepatitis B = 0.042 micron

Human Papilloma Virus (HPV) = 0.045 micron

Human Immunodeficiency Virus (HIV) = 0.18 micron

Mutagenicity: The occurrence of a sudden variation in some inheritable characteristic in a germ cell of an individual animal or plant.

Nucleic Acid: The genetic information of the virus is carried on nucleic acid, without which it cannot replicate. It may be deoxyribonucleic acid (DNA) or ribonucleic acid (RNA). It may be single- or double-stranded, in a single piece or several (segmented or multi-partite genome). For each virus the nature, size, strandedness and number of pieces are constant features.

Pathogen: Any disease-producing agent or microorganism.

Smoke Plume Capture: The purpose of all electrosurgical and laser smoke filtration systems. Plume capture effectiveness is a function primarily of suction velocity.

ULPA Filter: Ultra Low Penetration Air filters are used for the capture of sub-micron particles. The I.E.S definition of ULPA filters specifies an efficiency of 99.999% for particle diameters of 0.12 micron and larger. The efficiency percentage is required for the rating to be meaningful.

Virion, Virus Particle: These terms are virtually synonymous and refer to the complete virus as seen in the electron microscope. The terms also refer to fully infective particles. Virion is more strictly correct for the complete virus, virus particle being coined at a time when methods were less refined and virus structure less established.