TITLE: Surgical Smoke Exposure: Safety, Prevention, and Guidelines

DATE: 10 November 2011

RESEARCH QUESTIONS

1. What is the clinical evidence on the safety of surgical smoke exposure for patients and medical personnel in the operating room?

2. What is the clinical effectiveness of methods to mitigate surgical smoke exposure for patients and medical personnel in the operating room?

3. What are the evidence-based guidelines and recommendations regarding surgical smoke exposure for patients and medical personnel in the operating room?

4. What are the evidence-based guidelines and recommendations regarding methods to mitigate surgical smoke exposure for patients and medical personnel in the operating room?

KEY MESSAGE

The evidence indicates toxic gasses are present surgical smoke released in the operating room and adverse effects have been observed. The use of high quality filter masks and smoke evacuator systems are recommended to reduce exposure to such pollutants and prevent adverse events from occurring.

METHODS

A limited literature search was conducted on key resources including PubMed, The Cochrane Library (2011, Issue 10), University of York Centre for Reviews and Dissemination (CRD) databases, Canadian and abbreviated list of major international health technology agencies, as well as a focused Internet search. Methodological filters were applied to limit retrieval to health technology assessments, systematic reviews, meta-analyses, randomized controlled trials, non-
randomized studies and guidelines. Where possible, retrieval was limited to the human population. The search was also limited to English language documents published between January 1, 2006 and November 2, 2011. Internet links were provided, where available.

The summary of findings was prepared from the abstracts of the relevant information. Please note that data contained in abstracts may not always be an accurate reflection of the data contained within the full article.

RESULTS

Rapid Response reports are organized so that the higher quality evidence is presented first. Therefore, health technology assessment reports, systematic reviews, and meta-analyses are presented first. These are followed by randomized controlled trials, non-randomized studies, and evidence-based guidelines.

The literature search identified six non-randomized studies regarding the clinical evidence of the safety of surgical smoke and the methods to mitigate surgical smoke exposure for patients and medical personnel in the operating room. Additional references of potential interest are provided in the appendix.

OVERALL SUMMARY OF FINDINGS

The six non-randomized studies\(^1\)\(^{-}\)\(^6\) identified varied in terms of objective, methods, and results. A summary of their characteristics and key findings can be found in Table 1.

| Table 1: Characteristics and key findings of non-randomized controlled studies |
|-------------------------------|-----------------|---------------------------------------------|
| Study                         | Objective                                           | Results and Conclusions                                      |
| Dauser et al. 2011\(^1\)      | Assess the efficacy of a PVC when performing SILS. | - The addition of a PVC allowed for controlled smoke evacuation and increased visibility.  
- A reduction in contamination by constant air flow toward the PVC was also observed. |
| Chung et al. 2010\(^2\)       | Determine the chemical composition of surgical smoke produced during TURP and vaporization. | - Three of the toxic gases generated during TURP and vaporization were determined to be carcinogens.  
- Higher quality filter masks, smoke evacuation devices, or smoke filters should be developed for the safety of the operating room personnel and patients during TURP and vaporization. |
| Weston et al. 2009\(^3\)      | Identify any potentially harmful chemical compounds of the plume produced from urological endoscopic diathermy. | - Many different volatile organic hydrocarbons were produced, some of which are carcinogens.  
- The use of smoke evacuator systems for all urologists regularly performing these procedures is recommended. |
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<th>Study</th>
<th>Objective</th>
<th>Results and Conclusions</th>
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| Brüské-Hohlfeld et al. 2008<sup>4</sup> | To measure the amount of particulates in surgical smoke during different surgical procedures and to quantify the particle number concentration. | - Very high exposure to ultrafine particles for surgeons and close assisting operating personnel were seen in the short term.  
- Low exposure was seen over longer periods of time.  
- Exposure to particulate air pollution was associated with adverse cardiovascular and respiratory health effects. |
| Hubner et al. 2008<sup>5</sup>       | To analyze smoke samples produced during laparoscopic colon surgery using a bipolar vessel sealing device. | - The use of a vessel sealing device during laparoscopic surgery did not produce toxic substances in relevant quantity.                                    |
| Al Sahaf et al. 2007<sup>6</sup>   | Examine the toxic compounds found in surgical smoke released during electrosurgery. | - Irritant, carcinogenic, and neurotoxic compounds were found in electrosurgical smoke.  
- Exposure to the found compounds could pose implications to the health and safety of individuals involved in the OR. |

OR=operating room; PVC=peripheral venous catheter; SiLS=single-incision laparoscopic surgery; TURP=transurethral resection of the prostate
REFERENCES SUMMARIZED

Health Technology Assessments
No literature identified.

Systematic Reviews and Meta-analyses
No literature identified.

Randomized Controlled Trials
No literature identified.

Non-Randomized Studies


BACKGROUND: Getting the critical view in performing single-incision laparoscopic surgery (SILS) is challenging. In addition, visibility may be impaired by lens fogging and smoke accumulation in the abdomen produced by electrocautery or ultrasonic devices.

METHODS: In 12 patients undergoing single-incision laparoscopic cholecystectomy, a peripheral venous catheter (PVC) was introduced in the right upper quadrant under direct vision, and a three-way stopcock was screwed onto the catheter to allow controlled smoke evacuation. Cholangiography was attempted in all cases, four times by introducing a (CH5) feeding tube via PVC.

RESULTS: The described technique allowed controlled smoke evacuation via the PVC during SILS while reducing lens fogging and contamination by a constant air flow toward the venous catheter. Cholangiography was possible using a conventional cholangiography forceps (in 7 of 12 cases) or a feeding tube introduced via PVC (in 4 of 12 cases). Once, bleeding from an adjuvant vessel after incision of the cystic duct had to be controlled with clips, and no cholangiogram was achieved (in 1 of 12 cases). No procedure-related complications were observed. There was no conversion to conventional laparoscopic or open surgery. No visible scar was seen at the site of PVC introduction 5 weeks postoperatively.

CONCLUSIONS: Visibility can be improved in SILS using a PVC without leaving apparent scars. Cholangiography via PVC is technically feasible and allows complete assessment of the biliary tract.


OBJECTIVE: To determine the chemical composition of surgical smoke produced during transurethral resection of the prostate (TURP) and vaporization. METHODS: A total of 12 smoke samples were collected from a continuous irrigation suction drainage system to a Tenax absorber at a 0.05L/min flow rate during TURP and vaporization. The gases were quantitatively and qualitatively analyzed by gas chromatography-mass spectrometry (GC-MS) equipped with a purge and trap sample injector.

RESULTS: The main chemical constituents of surgical smoke produced during TURP and vaporization include propylene, allene, isobutylene, 1,3-butadiene, vinyl acetylene, mecaptomethane, ethyl acetylene, diacetylene, 1-pentene, EtOH, piperylene, propenylacetylene, 1,4-pentadiene, cyclopentadiene, acrylnitrite and butyrolactone. Three of the constituents are very toxic and carcinogenic (1,3-butadiene, vinyl acetylene and acrylonitrile). The amount (mean+/−standard deviation) of chemical
components in the 45L of gas and room air mixture produced during TURP and vaporization were as follows: propylene, 0.80+/−0.52mg; isobutylene, 212.85+/−75.65mg; 1,3-butadiene, 0.93+/−0.34mg; ethyl acetylene, 0.09+/−0.05mg; 1-pentene, 6.75+/−1.62mg; 1,4-pentadiene, 0.06+/−0.02mg; and acrylonitrile, 1.62+/−1.19mg. CONCLUSIONS: Three of the toxic gases generated during TURP and vaporization are carcinogens (1,3-butadiene, vinyl acetylene and acrylonitrile). Therefore, higher quality filter masks, smoke evacuation devices and/or smoke filters should be developed for the safety of the operating room personnel and patients during TURP and vaporization.


OBJECTIVES: To identify any potentially harmful chemical constituents of the gaseous plume produced from urological endoscopic diathermy. METHODS: Chemical analysis was performed on the gaseous plume produced from prostatic resections and vaporizations using gas chromatography with mass spectroscopy and high-performance liquid chromatography using ultraviolet and visible light detection. In addition, carbon monoxide levels were analyzed using a portable catalytic flammable gas sensor. RESULTS: This study identified a cocktail of volatile organic hydrocarbons produced during these procedures, some of which are known carcinogens. The most significant finding being high levels of carbon monoxide. CONCLUSIONS: From this preliminary study, we advocate the use of smoke evacuator systems for all urologists regularly performing these procedures, and suggest that further research is required to investigate potential long-term complications to the urologist.


BACKGROUND: Electrocautery, laser tissue ablation, and ultrasonic scalpel tissue dissection all generate a 'surgical smoke' containing ultrafine (<100 nm) and accumulation mode particles (< 1 mum). Epidemiological and toxicological studies have shown that exposure to particulate air pollution is associated with adverse cardiovascular and respiratory health effects. METHODS: To measure the amount of generated particulates in 'surgical smoke' during different surgical procedures and to quantify the particle number concentration for operation room personnel a condensation particle counter (CPC, model 3007, TSI Inc.) was applied. RESULTS: Electro-cauterization and argon plasma tissue coagulation induced the production of very high number concentration (> 100000 cm-3) of particles in the diameter range of 10 nm to 1 mum. The peak concentration was confined to the immediate local surrounding of the production side. In the presence of a very efficient air conditioning system the increment and decrement of ultrafine particle occurrence was a matter of seconds, with accumulation of lower particle number concentrations in the operation room for only a few minutes. CONCLUSION: Our investigation showed a short term very high exposure to ultrafine particles for surgeons and close assisting operating personnel - alternating with longer periods of low exposure.

BACKGROUND: Dissection during laparoscopic surgery produces smoke containing potentially toxic substances. The aim of the present study was to analyze smoke samples produced during laparoscopic colon surgery using a bipolar vessel sealing device (LigaSure trade mark). METHODS: Four consecutive patients undergoing left-sided colectomy were enrolled in this pilot study. Smoke was produced by the use of LigaSure trade mark. Samples (5.5l) were evacuated from the pneumoperitoneum in a closed system into a reservoir. Analysis was performed with CO2-laser-based photoacoustic spectroscopy and confirmed by a Fourier-transform infrared spectrum. The detected spectra were compared to the available spectra of known toxins. RESULTS: Samples from four laparoscopic sigmoid resections were analyzed. No relevant differences were noted regarding patient and operation characteristics. The gas samples were stable over time proven by congruent control measurements as late as 24 h after sampling. The absorption spectra differed considerably between the patients. One broad absorption line at 100 ppm indicating H2O and several unknown molecules were detected. With a sensitivity of alpha min ca 10⁻⁵ cm⁻¹ no known toxic substances like phenol or indole were identified. CONCLUSION: The use of a vessel sealing device during laparoscopic surgery does not produce known toxic substances in relevant quantity. Further studies are needed to identify unknown molecules and to analyze gas emission under various conditions.


BACKGROUND: Exposure to surgical smoke during electrosurgery may be harmful to theatre personnel. This study quantified toxic compounds present and we were particularly interested in isolating toluene, ethylbenzene and xylene due to their putative carcinogenic effects. METHODS: A variety of surgical procedures were studied. Smoke samples emitted during electrosurgery were collected in charcoal tubes and analysed by gas chromatography coupled with mass spectrometry. RESULTS: Surgery involving mainly thermal decomposition of adipose tissue produced greater quantities of aldehydes and lower concentrations of toluene. In contrast, smoke generated during epidermal tissue ablation produced higher levels of toluene, ethyl benzene and xylene. CONCLUSION: This study demonstrated the presence of irritant, carcinogenic and neurotoxic compounds in electrosurgical smoke. This may have considerable implications for the health and safety of all involved in surgical practice, as exposure to these compounds pose potential risks to health.

Guidelines and Recommendations
No literature identified.

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APPENDIX – FURTHER INFORMATION:

Review Articles


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, ultrasonic scalpels, high speed drills, burrs and saws. The potential risks include carbon monoxide toxicity to the patient undergoing a laparoscopic operation, pulmonary fibrosis induced by non-viable particles, and transmission of infectious diseases like human papilloma virus. Cytotoxicity and mutagenicity are other concerns. Minimisation of the production of surgical smoke and modification of any evacuation systems are possible solutions. In general, a surgical mask can provide more than 90% protection to exposure to surgical smoke; however, in most circumstances it cannot provide air-tight protection to the user. An at least N95 grade or equivalent respirator offers the best protection against surgical smoke, but whether such protection is necessary is currently unknown.


Electrosurgery, laser ablation, and ultrasonic scalpel dissection create a gaseous by-product commonly referred to as surgical smoke or plume. Smoke evacuation devices have been shown to be effective in limiting exposure to the noxious odor and potential health hazards of smoke and plume; however, these devices have not been used routinely and consistently in many ORs. This article reviews five quantitative research studies that explore the characteristics of smoke plume produced during surgery and presents the evidence of the need for consistent use of smoke evacuation systems.

Additional References


Surgical smoke presents a serious health hazard, but perioperative nurses’ compliance with smoke evacuation recommendations is not consistent. I investigated key indicators for compliance with electrosurgical smoke evacuation recommendations based on nurses’ individual innovativeness characteristics, perceptions
of the attributes of smoke evacuation recommendations, and organizational innovativeness characteristics. **The study findings provide implications for improving nurses’ compliance with smoke evacuation recommendations.** Individual innovativeness characteristics, including nurses’ knowledge and training, were **most strongly linked to smoke evacuation compliance.** The key indicators that promote surgical smoke evacuation can provide direction to guide the content of education programs and help identify the personnel and settings that are most in need of this information. Barriers to compliance included lack of equipment, physician resistance, noise, and staff member complacency. **Vendor demonstrations on the ease of smoke evacuation device use can show nurses that smoke evacuation is compatible with nursing practice.** Facility leaders should provide smoke evacuation policies that are easy to understand and should enforce these policies.


More than 500,000 health care workers are exposed to surgical smoke every year. Toxic gases create an offensive odor, small particulate matter causes respiratory complications, and pathogens may be transmitted in the surgical smoke to the surgical team. Previous research notes that perioperative nurses do not consistently follow smoke evacuation recommendations. **The purpose of this study was to determine key indicators that are associated with compliance with smoke evacuation recommendations.** Data from a web-based survey completed by 777 nurse members of AORN were analyzed to examine the relationship between the key indicators and compliance with smoke evacuation recommendations. **Major findings were that specific key indicators influencing compliance include increased knowledge and training, positive perceptions about the complexity of the recommendations, and increased specialization, interconnectedness, and leadership support in larger facilities.** Education programs can be developed that directly address these key predictors so that a surgical environment free from surgical smoke is promoted.


Surgical smoke is a part of the environment during operative and invasive procedures. As lasers and electrocautery have become commonplace, perioperative practitioners are at increased risk for health concerns associated with exposure to surgical smoke. Since the mid 1970s, the body of evidence documenting the hazardous components of surgical smoke has continued to grow. Despite the evidence and recommendations of a variety of organizations, there are no uniform requirements mandating surgical smoke evacuation. **This article reviews current research to identify the potential health hazards as well as the current recommendations related to the filtration and evacuation of surgical smoke.**


**Gaseous byproducts produced during electrocautery, laser surgery or the use of**
ultrasonic scalpels are usually referred to as ‘surgical smoke’. This smoke, produced with or without a heating process, contains bio-aerosols with viable and non-viable cellular material that subsequently poses a risk of infection (human immunodeficiency virus, hepatitis B virus, human papillomavirus) and causes irritation to the lungs leading to acute and chronic inflammatory changes. Furthermore, cytotoxic, genotoxic and mutagenic effects have been demonstrated. The American Occupational Safety and Health Administration have estimated that 500000 workers are exposed to laser and electrosurgical smoke each year. The use of standard surgical masks alone does not provide adequate protection from surgical smoke. While higher quality filter masks and/or double masking may increase the filtration capability, a smoke evacuation device or filter placed near (2-5 cm) the electrocautery blade or on endoscope valves offers additional (and necessary) safety for operating personnel and patients


BACKGROUND: Although pregnant personnel are commonly encouraged to leave the operating room during the mixing and application of polymethylmethacrylate, we are not aware of any information regarding the safety of exposure to methylmethacrylate fumes for breastfeeding women. The present study was performed to investigate the concentrations of methylmethacrylate in serum and breast milk following exposure during total joint arthroplasty. METHODS: A survey designed to determine present-day attitudes to polymethylmethacrylate exposure during pregnancy and lactation was sent to members of the Ruth Jackson Orthopaedic Society and the National Association of Orthopaedic Nurses. To define the presence or absence of a scientific basis for this behavior, serum and breast milk samples were collected from two lactating surgeons at selected intervals after exposure to methylmethacrylate during eight total joint arthroplasty procedures. Two healthy breastfeeding women without exposure to methylmethacrylate served as controls. All twenty-five samples were analyzed for methylmethacrylate with use of a previously published headspace gas chromatography protocol. RESULTS: The gas chromatography protocol detected methylmethacrylate at levels as low as 0.5 part per million. No serum or breast milk sample demonstrated evidence of methylmethacrylate at that level, nor did any surgeon sample test at a higher level than the control specimens. Serum and milk samples spiked with methylmethacrylate yielded the analyte peak as expected, evidencing no interference from either matrix. CONCLUSIONS: Methylmethacrylate was not detectable at the 0.5-part-per-million level in serum or breast milk following inhalational exposure during total joint arthroplasty. Although a controlled longitudinal relative risk analysis was not performed and the sample size was relatively small, pregnant or breastfeeding women may use this information to make an informed decision regarding such exposure. LEVEL OF EVIDENCE: Therapeutic Level II

Guidelines and Recommendations - methodology not specified

Resurfacing is a treatment to remove acne and chicken pox scars, and changes in the skin due to ageing. MACHINES: Both ablative and nonablative lasers are available for use. CO2 laser is the gold standard in ablative lasers. Detailed knowledge of the machines is essential. INDICATIONS FOR CO2 LASER: Therapeutic indications: Actinic and seborrheic keratoses, warts, moles, skin tags, epidermal and dermal nevi, vitiligo blister and punch grafting, rhinophyma, sebaceous hyperplasia, xanthelasma, syringomas, actinic cheilitis angiofibroma, scar treatment, keloid, skin cancer, neurofibroma and diffuse actinic keratoses. CO2 laser is not recommended for the removal of tattoos. AESTHETIC INDICATIONS: Resurfacing for acne, chicken pox and surgical scars, periorbital and perioral wrinkles, photo ageing changes, facial resurfacing. PHYSICIANS’ QUALIFICATIONS: Any qualified dermatologist (DVD or MD) may practice CO2 laser. The dermatologist should possess postgraduate qualification in dermatology and should have had specific hands-on training in lasers either during postgraduation or later at a facility which routinely performs laser procedures under a competent dermatologist/plastic surgeon, who has experience and training in using lasers. For the use of CO2 lasers for benign growths, a full day workshop is adequate. As parameters may vary in different machines, specific training with the available machine at either the manufacturer’s facility or at another centre using the machine is recommended. FACILITY: CO2 lasers can be used in the dermatologist’s minor procedure room for the above indications. However, when used for full-face resurfacing, the hospital operation theatre or day care facility with immediate access to emergency medical care is essential. Smoke evacuator is mandatory. PREOPERATIVE COUNSELING AND INFORMED CONSENT: Detailed counseling with respect to the treatment, desired effects, possible postoperative complications, should be discussed with the patient. The patient should be provided brochures to study and also given adequate opportunity to seek information. Detailed consent forms need to be completed by the patients. Consent forms should include information on the machine used; possible postoperative course expected and postoperative complications. Preoperative photography should be carried out in all cases of resurfacing. Choice of the machine and the parameters depends on the site, type of lesion, result needed, and the physician’s experience. ANESTHESIA: Localized lesions can be treated under eutectic mixture of local anesthesia (EMLA) cream anesthesia or local infiltration anesthesia. Full-face resurfacing can be performed under general anesthesia. Proper postoperative care is important to avoid complications.