

Surgical Smoke and the Orthopedic Implications

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Abstract

Introduction: Orthopedic surgeons encounter potential occupational hazards during every procedure. Recent studies highlight that numerous harmful chemical and biological compounds are present in electrocautery surgical smoke (ESS).

Methods: A systematic review was performed using data from MEDLINE and PubMed. The search resulted in over fifty articles that materially discussed one or more of the following topics: (1) the constituents detected in surgical smoke, (2) the methods used to analyze the smoke, (3) the health consequences of exposure, and (4) prospective risk reduction measures. We summarized the risks.

Results: Exposure to compounds isolated in ESS are associated with an increased risk for carcinogenesis as well as pulmonary and bone marrow damage. Transmission of infectious particles can occur even when standard precautions are taken. Of all the publications reviewed, only one article in the orthopedic literature referenced occupational hazards with a minor section devoted to ESS.

Discussion: Orthopedic surgeons need to be better informed of the hazards that result from ESS. Occupational exposure to ESS has real risks, which have been extrapolated from the literature and are remiss within the orthopedic literature. Further investigation is warranted regarding exposure and long-term sequelae of ESS. Practical solutions are needed to minimize risk to all operating room personnel.

INTRODUCTION

Orthopedic surgeons face numerous occupational hazards during every surgical case. Some of these risks are obvious, like communicable disease transfer through contact or needle sticks and radiation exposure. However, others are more obscure, like neck or low back pain and the focus of this paper, surgical smoke. Electrocautery is regarded by most surgical specialties as an essential intraoperative tool that can efficiently maintain hemostasis and aid in tissue dissection. Many orthopedic surgeries employ prolonged use of electrocautery, including complex spine and reconstructive procedures. As advancements are made in the field of orthopedic surgery, the number of surgical interventions performed, and therefore, the use of electrocautery will also continue to increase.

Numerous chemical and biologic compounds that have been independently demonstrated to be harmful are now being identified in this surgical smoke. Although various smoke filtration systems have been utilized in the operating room,

surgeons, who are typically in the closest proximity of the surgical site, are still being directly exposed to hours of aerosolized toxicity with minimal protection. These findings implicate an increased potential for carcinogenesis, pulmonary damage and infection transmission.

METHODS

A systematic review of the literature utilizing MEDLINE and PubMed was performed. The search resulted in over 50 (fifty) articles that materially discussed one or more of the following topics: (1) the constituents detected in surgical smoke, (2) the methods used to analyze the smoke, (3) the health consequences of exposure, and (4) prospective risk reduction measures. Of all the publications reviewed, only one article in the orthopedic literature referenced occupational hazards with a minor section devoted to ESS.¹ Additionally, a search of four well respected orthopedic journals (JBJS Am, JBJS Br, JAAOS, and CORR) with the queries of “surgical smoke” and “diathermy” resulted no relevant articles related to surgical smoke safety.

RESULTS

The hazards of ESS are well recognized by most surgical specialties, including general surgery and dermatology. Electrocautery has been shown to produce sub-micron sized particles that can be easily deposited in the pulmonary alveoli of those nearby.²⁻⁷ This smoke has been analyzed by

many authors and has been shown to contain hundreds of constituents that range from mere mucous membrane irritants to infectious bacterial and viral particles, and even carcinogens.^{2, 6-38} Tables 1 and 2 summarize the most significant and abundant ESS components and the potential exposure risks they pose.

Table 1

Compounds Detected in Electrocautery Surgical Smoke

Table 1: Compounds Detected in Electrocautery Surgical Smoke	
Name	Hazard
<u>Chemical</u>	
1,2-dichloroethane*	Carcinogen
Benzene*	Carcinogen
Ethanol	Carcinogen
Ethylbenzene	Carcinogen
Styrene	Carcinogen
Benzo[a]pyrene	Carcinogen
Acryl-nitrile	Carcinogen (Class 2a)
Acetone	Health Risk
Hexane	Health Risk
Toluene	Health Risk
p-xylene	Health Risk
o-xylene	Health Risk
Hydrogen cyanide	Health Risk
Carbon monoxide	Health Risk
Naphthalene	Health Risk
Aldehydes	Health Risk
Phenol	Health Risk
Chloroform	Health Risk
<u>Biologic</u>	
HIV	Infection Risk
HPV	Infection Risk
HBV	Infection Risk
HCV	Infection Risk
Pseudomonas aeruginosa	Infection Risk
S. aureus	Infection Risk
Corynebacterium	Infection Risk
Neisseria	Infection Risk
Fungi	Infection Risk
*Unacceptable risk according to EPA guidelines Health risk: acute and/or delayed toxicity identified Bold denotes chemicals frequently found in cigarette smoke	

Table 2

Health Risks

Table 2: Health Risks
<u>Carcinogenesis</u>
Malignant DNA Transformation
<u>Hematopoietic System Disorders</u>
Anemia
Bone Marrow Failure
Lymphoproliferative Disorders
Lymphoma
Leukemia
<u>Cardiovascular System</u>
Blood Vessel Hypertrophy
Myocardial Infarction
<u>Pulmonary System Disorders</u>
Interstitial Pneumonia
Alveolar Congestion
Bronchiolitis
Emphysema
Lung Cancer
<u>Infection Transmission</u>
HIV
HBV/HCV
HPV (Nasopharyngeal papillomatosis)
Pseudomonas aeruginosa
Staphylococcus aureus
Corynebacterium spp.
Neisseria spp.
Hyphae and arthrospores (Dermatophytic mycosis)
<u>Adverse Reactions</u>
Nausea
Emesis
Mucous membrane irritation

Transmission of infectious particles can occur even when standard precautions are taken. Hill et al. showed that five (5) minutes of electrocautery vaporized between 1 and 2 grams of human tissue into the smoke plume.³⁹ Combining their data with that of Tomita et al., they determined that during an average day in a plastic surgery operating room, the mutagenic equivalent of passively smoking 27 to 30 unfiltered cigarettes was produced.³⁶

DISCUSSION

It is universally accepted that excessive exposure to air pollution and cigarette smoke may have lethal consequences. As noted in Table 1, ESS contains many of these same compounds.^{38, 40-43} This has not gone unnoticed by governmental agencies. The National Institute for Occupational Safety and Health (NIOSH) has issued a Hazard Alert, which is their strongest recommendation.

In 1996, healthcare employees were first cautioned of the potential harm of surgical smoke and recommendations were implemented to reduce exposure through adequate ventilation and suction evacuation. Although the Occupational Safety and Health Administration (OSHA) does not have standards of ESS exposure, they do recommend personal protective equipment (PPE) be used at all times. They also support the use of smoke evacuation systems.

In addition, many laws protect workers from dangerous workplaces. Workman's compensation laws were enacted to protect workers from environments that may cause illness or injury.⁴⁴ With substantial evidence available in the literature and in response to many healthcare workers' concerns, federal recommendations regarding PPE and surgical devices have begun to improve.

Surgical respirators that meet or exceed current EN-14683 guidelines are available, including N95 respirators. The caveat is that these respirators must be worn snugly and the wearer be appropriately fit tested. In reality, surgical respirators are rarely, if ever, worn by surgeons or OR staff. The vast majority of the time, simple surgical masks are worn that are only designed to protect against splash and droplets. These masks allow for significant air leakage, and therefore, are not effective at filtering even the largest of particles.⁴⁵⁻⁴⁷ It has been shown that even togas and hoods in combination with the appropriate helmet do not effectively filter particles that can easily reach the gas exchanging portion of the lung. In fact, these companies recommend the concurrent use of respirators when

respiratory pathogens might be present.⁴⁸

In response to this growing concern, many electrosurgical companies now offer electrocautery devices with integrated smoke evacuation systems.⁴⁹⁻⁵⁰ Pillinger et al. have shown that appropriate use of suction near the source of production can decrease the amount of smoke reaching the surgeon's lungs by over 11 fold compared with no suction use.⁵¹ Although there is no proven solution for reducing the exposure and risk of ESS, the consensus among the majority is to combat this issue with a multi-layered approach consisting of adequate ventilation, excellent evacuation with suction and filtration systems, appropriate use of PPE, and most importantly education and awareness.^{2, 4, 7, 12, 39, 51}

CONCLUSION

Orthopedic surgeons need to be better informed of the hazards that result from ESS. Occupational exposure to ESS has real risks, which have been extrapolated from the published data and are remiss within the orthopedic literature. Exposure to compounds isolated in ESS are associated with an increased risk for carcinogenesis, as well as pulmonary and bone marrow damage. Further investigation is warranted regarding exposure and long-term sequelae of ESS. Practical solutions are needed to minimize risk to all operating room personnel.

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