NIOSH Investigations of Surgical Plume and Smoke Hazards

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Disclaimer

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Background

- Surgical plume: focus of attention as a potential occupational hazard to operating room (OR) personnel
  - surgical plume particles
  - chemical by-products produced
  - possible infectious agents aerosolized

- widespread use of surgical plume-producing equipment
- large number of OR personnel exposed to plume
- concern for acute and chronic health impacts

Several energy-based instruments, including:
- Electrosurgical unit (ESU)
- Harmonic scalpel
- Carbon dioxide (CO₂) and other lasers
- Neutral plasma coagulator

Commonality: destruction of tissue through energy applied to it and resultant production of considerable quantities of plume
Background

Each year, an estimated 500,000 workers, including surgeons, nurses, anesthesiologists, and surgical technologists, are exposed to laser or electrosurgical smoke.

NIOSH HHEs (1985–1990)

- University of Utah, UT (1990)
  - Laser surgical procedures:
  - Health effects reported:
  - Particle mass concentrations:
    - range: 0.4–9.4 milligrams per cubic meter of air (mg/m³)
    - mean: 2.75 mg/m³
  - No specific organic vapors, other than isopropanol, detected
  - No polynuclear aromatic compounds (PNAs) or nitrosamines detected
  - Solvent extracts of airborne particles were mutagenic to the Salmonella typhimurium TA 98 strain
  - Conclusion: potential hazard from exposures on basis of mutagenicity and acute health effects reported

NIOSH HHEs (1985–1990)

- Bryn Mawr Hospital, PA (1988)
  - Electrocautery knife use during reduction mammoplasty surgeries
  - Health effects reported:
    - headache, nausea, upper respiratory and eye irritation
  - Particle mass concentrations:
    - range: 0.4–9.4 mg/m³
    - mean: 2.75 mg/m³
  - No specific organic vapors, other than isopropanol, detected
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NIOSH Hazard Control (1996)

- Falls Church, VA; Charlotte, NC; and Dunedin, FL hospitals:
  - symptom questionnaire (66–92% response rate)
  - surgical nurses, anesthetists, and surgical technicians
    - at least 1 symptom associated with plume exposure: 36–52%
    - eye irritation: 10–24%
    - burning of nose or throat: 13–18%
    - headache: 16–21%
    - coughing: 10–24%
    - nasal symptoms 3–16%
    - asthma or asthma-like symptoms after beginning work in OR: 2–24%
  - personal breathing zone (PBZ) and area air samples collected:
    - 15 procedures over 3 days at each hospital
    - sampled for: volatile organic compounds (VOCs), acrolein, phenol, cresols, hydrogen cyanide, formaldehyde, acetaldehyde, polycyclic aromatic compounds, carbon monoxide, direct-reading particle monitoring
    - results: quantified formaldehyde, acetaldehyde, toluene, but well below applicable OELs
"There have been too few studies, each accounting for different tissue types, laser devices, and operational parameters to draw any definitive conclusions with respect to the true range of particulate matter diameter. Furthermore, several of these studies sampled at locations that were within centimeters of the operative site; thus, it is not clear how the size distributions measured correspond to those experienced in the breathing zone of laser operators. The generation of a more comprehensive data set that is representative of the various possible exposure scenarios is imperative for designing adequate control strategies."

Aim 1: Point of Generation

- Background geometric mean (GM) particle number concentrations:
  - 53–67 particles/cm³

Electrocautery knife (cut), without LEV:
- Particle Number and Respirable Mass Concentrations

Electrocautery (coag) LEV Electrocautery (coag) no LEV

Aim 2: PBZ

- Surgical instruments used for plume generation:
  - electrosurgical unit (ESU)
  - harmonic scalpel
  - carbon dioxide (CO₂) laser
  - neutral plasma coagulator
- Skin and fat tissue
- Measurements at PBZ of surgeon:
  - particle size distribution
  - particle number concentration
- Measurements in OR periphery:
  - particle number concentrations
Aim 2: PBZ

- Count median diameter:
  - Smallest: 0.028–0.038 µm (harmonic scalpel) vs. 0.024 µm*
  - Largest: 0.088–0.190 µm (ESU) vs. 0.095 µm*

- GM particle number concentrations:
  - Surgeon:
    - Lowest: 200–500 p/cm³ (harmonic scalpel) vs. 711,000 p/cm³
    - Highest: 68,000–109,000 p/cm³ (neutral plasma coagulator) vs. 15,200,000 p/cm³
  - Periphery of room:
    - Lowest: 50–500 p/cm³ (harmonic scalpel)
    - Highest: 37,000–67,000 p/cm³ (neutral plasma coagulator)

*Italicized data indicate results from point of generation measurements for comparison.

Aim 3: Surgeries

- Surgical suite field studies:
  - Hospital operating room in NY State
  - HEPA filtered air
  - ~22-25 air changes per hour (ACH)

- Worker focus:
  - Primary: near the surgical table
  - Secondary: at the periphery of the room

- Selected procedures:
  - Two plume-producing instruments (electrosurgical unit and neutral plasma coagulator) and multiple tissue cuts

- Direct-reading monitoring:
  - Before and throughout the course of the procedure.

- Thighplasty and brachioplasty (ESU and neutral plasma coagulator)
  - CMD: 0.091–0.105 µm
  - GM particle number concentration: 8,500–24,000 p/cm³
  - Max particle number concentration: 136,000 p/cm³
  - With LEV, CMD: 0.035–0.042 µm
  - 84–92% reduction in GM particle number concentrations

- Breast augmentation (ESU and neutral plasma coagulator)
  - CMD: 0.098–0.099 µm after ESU or neutral plasma coagulator use
  - CMD: 0.035 µm after neutral plasma coagulator for antibacterial use
  - GM particle number concentration: 230–250 p/cm³
  - Max particle number concentration: 6,800 p/cm³

- Necrotic tissue removal (ESU)
  - CMD: 0.092 µm after ESU use
  - GM particle number concentration: 890–1,900 p/cm³
  - Max particle number concentration: 11,000 p/cm³
Specific Aim 3: Surgeries

Thighplasty without LEV use:
- 84–92% reduction
- in GM particle number conc.

Thighplasty with LEV use:
- 100,000
- 80,000
- 60,000
- 40,000
- 20,000
- 0

Recent Research Articles

- Surgical smoke collected in real time in cell culture media by using an electrocautery device to cut and coagulate human breast tissues, followed by exposure to human small airway epithelial cells (SAEC) and mouse macrophages (RAW)
- Airborne particle number concentration and particle distribution
- Airborne concentration of selected volatile organic compounds (VOCs)
- Chemical properties and in vitro cellular toxicity were analyzed

Sampling in Medical Office Environment

Use of Neutral Plasma Coagulator

Recent Research Articles

- Average count median diameters: 0.092 µm
- Average particle number concentrations: 900–5,400 p/cm³
- Acetaldehyde, ethanol and isopropyl alcohol detected in every sample with higher concentrations compared to other VOCs
- Surgical smoke caused approximately 25% cell death in the SAEC and 40% in the RAW cells compared to background and field blank
- Toxic in both the SAEC and RAW although to varying degrees

Surgical Plume Particle Characterization Study

Recommendations:
- Develop employer policies for utilizing local exhaust ventilation controls when using equipment that produces surgical plume
- Train hospital and medical office staff on the potential hazards of surgical plume and control methods that can be used to minimize exposures
- Ensure operating rooms achieve recommended minimum total and outdoor air changes per hour and are maintained under positive pressure relative to adjacent corridors

Recent Research Articles

- Surgical smoke generated from human tissue in an unoccupied operating room using an electrocautery device for 15 min
  - (1) without LEV control
  - (2) control with a wall irrigation suction unit with an in-line ultra-low penetration air filter
  - (3) control with a smoke evacuation system
- Particle number and mass concentrations were measured
- Selected VOCs were collected
Recent Research Articles

- Alcohol and isopropyl alcohol were predominantly detected in every sample with relatively high concentrations compared to other VOCs
- Average ratios of LEV controls to without LEV control ranged 0.24–0.33 (particle number concentration) and 0.14–0.31 (particle mass concentration)

NIOSH HCW Survey: Surgical Smoke

- Surgical smoke questions:
  - control practices for those who work within 5 feet of a source
  - years exposed
  - hazard training
  - workplace procedures and guidelines that address surgical smoke from laser surgery and/or electrosurgery

NIOSH HCW Survey

  - anonymous, web-based
  - multi-module:
    - aerosolized medications
    - anesthetic gases
    - antineoplastic drugs
    - chemical sterilants
    - high level disinfectants
    - surgical smoke

NIOSH HCW Survey: Surgical Smoke

- Study population (n=4,533 respondents):
  - members of professional practice organizations representing healthcare occupations which routinely come in contact with surgical smoke, including:
    - nurse anesthetists
    - anesthesiologists
    - surgical technologists and assistants
    - perioperative nurses

NIOSH HCW Survey: Surgical Smoke

- Results: Local Exhaust Ventilation (LEV)
  - always used: 47%L, 14%E
  - never used: 31%L, 59%E
  - recommendation:
    - have employees use LEV for all procedures where surgical smoke is generated
  - L = laser surgery, E = electrosurgery

NIOSH HCW Survey: Surgical Smoke

- Results: Hazard training
  - never received: 49%, 44%E
  - received >12 months ago: 29%, 32%E
  - recommendation:
    - train employees on hazards and methods to minimize exposure prior to working in areas where surgical smoke is generated
NIOSH HCW Survey: Surgical Smoke

Results: Employer procedures
- no employer standard procedures addressing surgical smoke hazards: 31%, 29%
- unknown if employer had standard procedures: 39%, 40%
- recommendation:
  - ensure procedures that address the hazards of surgical smoke are available

NIOSH HCW Survey: Surgical Smoke

Results: Personal protective equipment
- N95 always used: 6%, 1%
- N95 never used: 90%, 98%
- laser & surgical masks used: 90%, 98%
- recommendation:
  - use a properly fitted, filtering facepiece respirator (e.g., N95) rather than a surgical or laser mask, especially in situations where LEV is lacking

Health Effects Research

- Few well-designed, large scale epidemiological studies of HCW populations investigating extent of health effects from plume exposure
- animal model studies of effects in the literature
- smaller comparative studies and questionnaires shown that exposure associated with acute eye and respiratory irritation, at minimum
- handful of case reports of laryngeal papillomas
- Vital to continue to investigate the risk of health effects that health care workers are under

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Thank You

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https://www.cdc.gov/niosh/topics/healthcarehsp/ smoke.html