Evidence Table
Guideline for Surgical Smoke Safety
December 15, 2016

Reference Numner	CITATION	CONCLUSION(S)	CONSENSUS SCORE	EVIDENCE TYPE	POPULATION	INTERVENTIONS	COMPARISON	SAMPLE SIZE	OUTCOME MEASURE
1	Ulmer BC. The hazards of surgical smoke. AORN J. 2008;87(4):721-734.	Eliminating a controllable hazard such as smoke can minimize health costs and improve the health of perioperative personnel and their patients. Efforts to control this environmental occupational hazard, will benefit perioperative personnel and patients.	VB	Literature review	NA	NA	NA	NA	NA
2	Ott DE. Proposal for a standard for laser plume filter technology. J Laser Appl. 1994;6(2):108-110.	Smoke evacuators are essential devices to protect patients and healthcare workers from serious side effects of surgical smoke. A methodology is needed to appraise and assess the efficiency of filters used in smoke evacuation systems.	IIB	Literature review	NA	NA	NA	NA	NA
3	Stephenson DJ, Allcott DA, Koch M. The presence of P22 bacteriophage in electrocautery aerosols. In: Proceedings of the National Occupational Research Agenda Symposium. Salt Lake City, UT; 2004.	Viable viral material can be transferred via aerosol generation produced by an electrosurgical unit. The results suggest that viable infectious agents can be aerosolized during electrocautery surgery. More studies are needed and a smoke evacuator should be used during all electrocautery procedures to minimize exposure of OR personnel to airborne infectious agents.	IIB	Quasi-experimental	Solid virus-containing agarose growth media	Electrocautery	Plates inoculated with live P22 bacteriophage virus and control plates with no bacteria	6	Presence of P22 bacteriophage in smoke produced by surgical instrument
4	Bratu AM, Petrus M, Patachia M, Dumitras DC. Carbon dioxide and water vapors detection from surgical smoke by laser photoacoustic spectroscopy. UPB Scientific Bulletin, Series A: Applied Mathematics and Physics. 2013;75(2):139-146.	A concentration of water vapors from 1% to 11% and a concentration of carbon dioxide in the range of 1.34 ÷ 8.6% were measured in the surgical plume.	IIB	Quasi-experimental	Animal tissue samples	CO2 laser	Different laser powers and different irradiation times	10	Components of carbon dioxide and water vapors

5	Tomita Y, Mihashi S, Nagata K, et al. Mutagenicity of smoke condensates induced by CO2-laser irradiation and electrocauterization. Mutat Res. 1981;89(2):145-149.	The findings suggest that the primary mutagens I the condensates may be premutagen requiring metabolic activation and may induce frameshift type mutation. The mutagenic ability of the laser condensates was half of the electrocautery. The electrocautery conditions may be more favorable for the generation of mutagens than laser radiation. The mutagenic potency of lasers condensates for 1 gram of tissue was comparable to cigarette smoke- 3 cigarettes for lasers and 6 cigarettes for electrocautery . More research is needed to evaluate human health hazards of laser and electrocautery smoke and the potential hazards of the healthcare workers should be remembered.	IIB	Quasi-experimental study	Animal tissue	Generation of smoke condensates with a CO2 laser and electrocauterization	Smoke condensates generated by CO2 irradiation and electrocauterization	NA	Amount of smoke condensates; mutation assay

6	Safety and Health Topics: Laser/Electrosurgery Plume. Occupational Safety and Health Administration. https://www.osha.gov/SLTC/laserelectrosurgeryplume/. Accessed September 20, 2016.	During surgical procedures that use a laser or electrosurgical unit, the thermal destruction of tissue creates a smoke byproduct. Each year, an estimated 500,000 workers, including surgeons, nurses, anesthesiologists, and surgical technologists, are exposed to laser or electrosurgical smoke. Surgical plumes have contents similar to other smoke plumes, including carbon monoxide, polyaromatic hydrocarbons, and a variety of trace toxic gases. Surgical smoke can produce upper respiratory irritation, and have in-vitro mutagenic potential. There has been no documented transmission of infectious disease through surgical smoke, but the potential for generating infectious viral fragments, particularly following treatment of venereal warts, may exist. Local smoke evacuation systems have been recommended by consensus	VA	Expert opinion	NA	NA	NA	NA	NA
7	Ball K. Compliance with surgical smoke evacuation guidelines: implications for practice. AORN J. 2010;92(2):142-149.	Perioperative nurses exposed to surgical smoke will continue to be at high risk for the development of respiratory problems if this hazard is not addressed appropriately through a change of culture and the implementation and acceptance of evidence-based guidelines.	IIIB	Non-experimental	AORN staff nurses	Survey	NA	777	Compliance with smoke evacuation
8	Ball K. Compliance with surgical smoke evacuation guidelines: implications for practice. ORNAC J. 2012;30(1):14-16.	Perioperative nurses exposed to surgical smoke will continue to be at high risk for the development of respiratory problems if this hazard is not addressed appropriately through change of culture and the implementation and acceptance of evidence-based guidelines.	IIIB	Non-experimental	AORN staff nurses	Survey	NA	777	Compliance with smoke evacuation

9	Calero L, Brusis T. Laryngeal papillomatosis—first recognition in Germany as an occupational disease in an operating room nurse. Laryngorhinootologie. 2003;82(11):790-793.	A case study of the development of laryngeal HPV in an OR male nurse regularly exposed to HPV-infected laser plume during surgical procedures in the OR.	VB	Case study	OR nurse	NA	NA	1	Laryngeal papillomatosis
10	Hallmo P, Naess O. Laryngeal papillomatosis with human papillomavirus DNA contracted by a laser surgeon. Eur Arch Otorhinolaryngol. 1991;248(7):425-427.	A 44 year old surgeon with a negative history of laryngeal HPV transmission develops laryngeal HPV. The report investigates his career as a laser surgeon regularly engaging in laser surgery of HPV laryngeal warts.	VB	Case study	Laser surgeon	NA	NA	NA	Cross-contamination with laryngeal HPV
11	Rioux M, Garland A, Webster D, Reardon E. HPV positive tonsillar cancer in two laser surgeons: case reports. J Otolaryngol Head Neck Surg. 2013;42:54.	A review of two cases suggesting that HPV generated in surgical plume can cause subsequent squamous cell carcinoma in the laser operator. There is a strong body of evidence supporting a causal relationship between oncogenic HPV types and head and neck squamous cell carcinomas/ HPV may be transmitted through laser plume.	VB	Case report	Laser surgeons	NA	NA	2	Exposure to and development of laryngeal HPV or laryngeal cancer
12	Weld KJ, Dryer S, Ames CD, et al. Analysis of surgical smoke produced by various energy-based instruments and effect on laparoscopic visibility. J Endourol. 2007;21(3):347-351.	Surgical smoke is composed of 2 distinct particle populations. Small particles are caused by the nucleation of vapors as they cool and the large particles are caused by the entrainment of tissue secondary to mechanical aspects. The high concentration of small particle is most responsible for the deterioration in laparoscopic visibility. The surgical plume generated by bipolar and ultrasonic instruments generate the least deterioration of visibility.	IIB	Quasi-experimental study	Fresh porcine psoas muscle tissue	Use of the different energy devices	Four instrument types (ie, harmonic scalpel, bipolar macroforceps, monopolar shears, and floating ball) were evaluated for their effect on laparoscopic visibility compared to the background	5	Degradation of visibility calculated using measured size-distribution data and the Rayleigh and Mie light-scattering theories.; particle size, and particle distribution
13	Khoder WY, Stief CG, Fiedler S, et al. In-vitro investigations on laser-induced smoke generation mimicking the laparoscopic laser surgery purposes. J Biophotonics. 2015;8(9):714-722.	Smoke generation depends on the size of the wavelength used when ablating tissue.	IIA	Quasi-experimental study	Animal tissue samples	Laser ablation generating surgical smoke	Different treatment wavelengths of 980nm, 1350nm, and 1470nm	20	Smoke generation affecting the quality of vision during laparoscopic surgery

14	Loukas C, Georgiou E. Smoke detection in endoscopic surgery videos: a first step towards retrieval of semantic events. Int J Med Robot. 2015;11(1):80-94.	The irregular movement of smoke was captured robustly by the proposed features, which could also be employed for interpretation of other semantic occurrences in surgical videos	IIIA	Non-experimental-descriptive study	Laparoscopic cholecystectomy patient videos and individual shots	Use of an one-class support vector machine (OCSVM)	OCSVM versus smoke detection method employed in fire surveillance	3	Detection of surgical smoke in laparoscopic video streams
15	da Silva RD, Sehrt D, Molina WR, Moss J, Park SH, Kim FJ. Significance of surgical plume obstruction during laparoscopy. JSLS. 2014;18(3).	A review of the literature aimed to increase understanding of surgical plume obstruction	VB	Literature review	NA	NA	Review of articles that quantify surgical smoke	NA	Quantification of surgical smoke
16	Wu JS, Monk T, Luttmann DR, Meininger TA, Soper NJ. Production and systemic absorption of toxic byproducts of tissue combustion during laparoscopic cholecystectomy. J Gastrointest Surg. 1998;2(5):399-405.	Laparoscopic cholecystectomy using electrocautery during dissection of the gallbladder resulted in hazardous levels of intraperitoneal carbon monoxide. Adverse effects of smoke exposure were not found to be attributable to levels of CO or other chemical byproducts. There was no evidence of elevated carbon monoxide in the surgeon. Production and release of smoke during laparoscopic cholecystectomy using monopolar electrocautery does not appear to be a threat to the patient or the surgeon.	IIB	Quasi-experimental study	Laparoscopic cholecystectomy patients and surgeons	Monopolar electrocautery in a CO2 pneumoperitoneum	The relationship between levels of intraperitoneal carbon monoxide and systemic carboxyhemoglobin and methemoglobin; Surgeon's pre-operative and post-operative levels of carboxyhemoglobin and methemoglobin	21 patients and 21 surgeons	Patient's level of intraabdominal carbon monoxide, systemic methemoglobin and carboxyhemoglobin, intraperitoneal hydrogen cyanide; and surgeon's levels of carboxyhemoglobin and methemoglobin
17	Takahashi H, Yamasaki M, Hirota M, et al. Automatic smoke evacuation in laparoscopic surgery: a simplified method for objective evaluation. Surg Endosc. 2013;27(8):2980-2987.	Automatic smoke evacuators provide better field-of-view and reduces the risk of exposure. Subjective field visibility was better in the group with an automatic smoke evacuator system. The amount of surgical smoke was significantly less in the evacuation group vs. the control group.	IIB	Quasi-experimental study	Surgeons	Automatic smoke evacuator	Smoke evacuation vs no smoke evacuation and objective versus subjective analysis of visibility	10	Component analysis of sampled surgical smoke; subjective surgeon analysis of the field-of-view; objective analysis of the field-of-view using an industrial smoke-analysis device
18	Divilio LT. Improving laparoscopic visibility and safety through smoke evacuation. Surg Laparosc Endosc. 1996;6(5):380-384.	Lasevac smoke evacuator device allows exchange of opacified abdominal gas for fresh carbon dioxide without the periodic or continuous venting of smoke into the OR	VB	Literature review	NA	NA	NA	NA	NA

19	Alp E, Bijl D, Bleichrodt RP, Hansson B, Voss A. Surgical smoke and infection control. J Hosp Infect. 2006;62(1):1-5.	Surgical smoke and aerosols are irritating to the lungs and have mutagenicity of cigarette smoke. Risks are cumulative and greater closer to the point of production. Surgical masks alone do not provide adequate protection against surgical smoke. A smoke evacuation device near the site of smoke generation offers additional and necessary protection for patients and OR personnel.	VB	Literature review	NA	NA	NA	NA	NA
20	Barrett WL, Garber SM. Surgical smoke: a review of the literature. Business Briefing: Global Surgery. 2004:1-7.	Hazards of surgical smoke are evident in the literature; surgeons and OR personnel should be aware of the hazards and use measures (eg, smoke evacuators) to minimize exposure. Human to human viral transmission via laser smoke can occur. Electrocautery generates carbon monoxide in the peritoneal cavity.	VA	Literature review	NA	NA	NA	NA	Hazard of surgical smoke
21	Ansell J, Warren N, Wall P, et al. Electrostatic precipitation is a novel way of maintaining visual field clarity during laparoscopic surgery: a prospective doubleblind randomized controlled pilot study. Surg Endosc. 2014;28(7):2057-2065.	Ultravision improves visibility during laparoscopic surgery and reduces case delay times for smoke clearance.	IB	Randomized controlled trial	Laparoscopic Cholecystectomy Patients	Ultravision Device	Control (no device) vs Ultravision Device	30	Field visibility based on surgical smoke presence

22	Wu JS, Luttmann DR, Meininger TA, Soper NJ. Production and systemic absorption of toxic byproducts of tissue combustion during laparoscopic surgery. Surg Endosc. 1997;11(11):1075-1079.	Laparoscopic tissue combustion increases intra-abdominal carbon monoxide to levels above those established as safe by the EPA and OSHA leading to minimal elevations of carboxyhemoglobin that were statistically significant. The magnitude does not seem to pose a clinical threat. Systemic methemoglobin and intraabdominal hydrogen cyanide, acrylonitrile and benzene are not elevated to toxic levels. Hydrogen cyanide reached the upper safety limit for ambient concentrations. Production of intraperitoneal smoke may not pose a health risk to the patient. Additional research is needed to determine the clinical significance of hydrogen cyanide and acrylonitrile and to quantify the concentration of other potentially chemical byproducts of laparoscopic tissue combustion.	IIB	Quasi-experimental study	Animals	Monopolar electrocautery in a CO2 pneumoperitoneum	The relationship between levels of intraperitoneal carbon monoxide and systemic carboxyhemoglobin and methemoglobin	7	Intraabdominal carbon monoxide, systemic methemoglobin and carboxyhemoglobin, intraperitoneal hydrogen cyanide; and surgeon's inhalation of carbon monoxide from ambient smoke exposure
23	Fletcher JN, Mew D, Descôteaux J-G. Dissemination of melanoma cells within electrocautery plume. Am J Surg. 1999;178(1):57-59.	The study confirms that the application of electrocautery to a pellet of melanoma cells releases these cells into the plume. The cells are viable and may be grown in culture. The release may explain the appearance of port metastases at sites remote from the surgical dissection or that were never in direct contact with the tumor.	IIB	Quasi-experimental study	B16 melanoma cells	Electrocautery	Fulguration at 10,20, 30 Watts	3	Presence of viable malignant cells in suspension within electrocautery plume.
24	Ott DE. Carboxyhemoglobinemia due to peritoneal smoke absorption from laser tissue combustion at laparoscopy. J Clin Laser Med Surg. 1998;16(6):309-315.	Carbon monoxide is created in large quantities during laparoscopy with lasers and is absorbed through the peritoneal cavity. Symptoms of smoke poisoning is seen with the elevation. Removal of smoke is recommended.	IIB	Quasi-experimental study	Patients undergoing laparoscopic procedures	Control group-no laser or cautery used; Study group-CO2 laser used during laparoscopy.	Evaluation of preoperative, intraoperative, & postoperative levels of carboxyhemoglobin and pulse oximetry	50	Absorption of carbon monoxide from the peritoneal cavity resulting from laser use during laparoscopy.

25	Esper E, Russell TE, Coy B, Duke BE 3rd, Max MH, Coil JA. Transperitoneal absorption of thermocauteryinduced carbon monoxide formation during laparoscopic cholecystectomy. Surg Laparosc Endosc. 1994;4(5):333-335.	Thermocautery produces carbon monoxide which builds in the peritoneum; however, brief intervals of exposure may explain why patient carboxyhemoglobin levels remain unchanged.	IIB	Quasi experimental	Laparoscopic cholecystectomy patients	Thermocautery	Various stages during surgical procedure	15	Intraperitoneal carbon monoxide levels and carboxyhemoglobin blood levels
26	Control of smoke from laser/electric surgical procedures. National Institute for Occupational Safety and Health. Appl Occup Environ Hyg. 1999;14(2):71.		IVA						
27	IFPN guideline on risks, hazards, and management of surgical plume. 2015. International Federation of Perioperative Nurses. http://www.ifpn.org.uk/guidelines/Surgical_Plume_-_Risks_Hazards_and_Management.pdf. Accessed September 20, 2016.	It is important that Employers and Employees are aware of the risks and hazards associated with exposure to surgical plume and ensure that there are policies in place to reduce that exposure. Surgical policies must comply with Workplace and/or Occupational health and safety laws, International Electro-technical Commission (IEC) and ISO (International Standards Organization) standards, professional best practices, and other local rules and guidance to the healthcare setting.	IVB	Clinical practice guideline	NA	NA	NA	NA	NA
28	Standard: surgical plume. In: 2014-2015 ACORN Standards for Perioperative Nursing: Including Nurses Roles, Guidelines, Position Statements, Competency Standards. Adelaide, SA: Australian College of Operating Room Nurses; 2014:149-153.	The standard was developed to give direction on the management of surgical plume. Plume is generated during by tissue ablation with electrosurgical devices, radio frequency units, ultrasonic devices and laser. ACORN believes patients and surgical personnel should be protected from exposure and the hazards of surgical plume.	IVB	Clinical Practice Guideline	NA	NA	NA	NA	NA
29	ORNAC Standards for Perioperative Registered Nursing Practice. 12 ed. Kingston, ON: Operating Room Nurses Association of Canada; 2015.	Practice standards and requirements for the perioperative registered nurse.	IVB	Clinical practice guideline	NA	NA	NA	NA	NA

30	AST Standards of Practice for Use of Electrosurgery. 2012. Association of Surgical Technologists. http://ww.ast.org/uploadedFiles/Main_Site/Content/About_Us/Standard%20Electrosurgery.pdf. Accessed September 20, 2016.	Electrosurgical plume evacuation and filtering should be performed during a surgical procedure when the monopolar ESU is used including the harmonic scalpel.	IVB	Clinical Practice Guideline	NA	NA	NA	NA	NA
31	AST Standards of Practice for Laser Safety. 2010. Association of Surgical Technologists. http://www.ast.org/uploadedFiles/Main_Site/Content/About_Us/Standard%20Laser%20Safety.pdf. Accessed September 20, 2016.	Laser plume evacuation and filtering must be performed during a laser surgical procedure	IVB	Clinical Practice Guideline	NA	NA	NA	NA	NA
32	Steege AL, Boiano JM, Sweeney MH. Secondhand smoke in the operating room? Precautionary practices lacking for surgical smoke. Am J Ind Med. June 10, 2016. Epub ahead of print. doi: 10.1002/ajim.22614.	The study represents the largest survey describing practices around surgical smoke of a diverse group of healthcare workers. Despite guidance documents recommending smoke evacuation, the survey found that evacuation to remove smoke is not always used. Only 47% of the respondents used evacuation during laser surgery and 14% used it during electrosurgery. Evacuation was more consistently used where the employees received education on the hazards of surgical smoke. Employers should develop standard procedures to evacuate smoke to protect all healthcare personnel from the hazardous smoke exposure. Smoke evacuation should not be at the discretion of one practitioner as all are exposed to the smoke.	IIIA	Non-experimental-descriptive	Nurses, anesthesia providers, OR personnel, physicians	NA	NA	4533	Use of exposure controls, barriers to suing local exhaust ventilation, and PPE including respiratory protection

33	Steege AL, Boiano JM, Sweeney MH. NIOSH health and safety practices survey of healthcare workers: training and awareness of employer safety procedures. Am J Ind Med. 2014;57(6):640-652.	A survey of seven hazard modules, a core module, and a screening module focusing on health and safety practices of individuals representing 21 different organizations. The survey was a cost-effective surveillance tool to assess the current health and safety practices of healthcare workers. The data provides insight on the availability of training and education and procedures for minimizing exposure risk.	IIIB	Non-experimental	Nurses, anesthesia providers, OR personnel, physicians	NA	NA	12228	Training and employer standard procedures
34	Spearman J, Tsavellas G, Nichols P. Current attitudes and practices towards diathermy smoke. Ann R Coll Surg Engl. 2007;89(2):162-165.	The use of smoke evacuation equipment amongst the surgeons who responded to the questionnaire was low. Greater awareness of the hazards of surgical smoke and available technology to evacuate the smoke from the OR may lead to greater use of smoke evacuation.	IIIB	Non-experimental-descriptive	General surgical consultants, specialist registrars, and senior theatre nurses	NA	General surgical consultants versus specialist registrars	118	Smoke evacuator use and opinions of surgical smoke hazards
35	Lopiccolo MC, Balle MR, Kouba DJ. Safety precautions in Mohs micrographic surgery for patients with known blood-borne infections: a survey-based study. Dermatol Surg. 2012;38(7 Part 1):1059-1065.	Mohs surgeons reported no known exposures with the use of smoke evacuation devices, blunt skin hooks, safety scalpels, or safety syringes. The data suggest that adopting a standard set of safety measures for all patients may help reduce the rate of exposure injuries in Mohs micrographic surgery.	IIIA	Non-experimental-descriptive study	MOHS Surgeons	Survey of safety procedures	Precautionary measures and perceived exposure	188	Double gloving, wearing respirators, using blunt skin hooks, using safety scalpels, using safety syringes, and using smoke evacuation. Exposure injury rates
36	Edwards BE, Reiman RE. Comparison of current and past surgical smoke control practices. AORN J. 2012;95(3):337-350.	The use of wall suction as a control measure has increased for most procedures on the survey; progress in the adoption of other control measures has been mixed, with improvement for some procedures, no change for most procedures, and a decrease in compliance for a few procedures.	IIIB	Non-experimental	AORN members	Survey	Compared results to 2007 survey	1356	Compliance with best practices for smoke evacuation

37	Edwards BE, Reiman RE. Results of a survey on current surgical smoke control practices. AORN J. 2008;87(4):739-749.	Most facilities surveyed have not implemented best practices for protecting patients and health care workers from surgical smoke hazards, especially smoke created during electrosurgical, electrocautery, and diathermy procedures	IIIB	Non-experimental	AORN members	Survey	NA	623	Compliance with best practices for smoke evacuation
38	PL 91–596. Occupational Safety and Health Act of 1970. December 29, 1970, as amended through January 1, 2004. Occupational Safety and Health Administration. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=OSHACT&p_id=2743. Accessed September 21, 2016.	Regulations aimed to assure safe and healthful working conditions for working men and women.	Regulatory	Regulatory	NA	NA	NA	NA	NA
39	OSHA General Duty Clause. Occupational Safety and Health Administration. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=OSHACT&p_id=3359. Accessed September 21, 2016.	Basic outline of occupational safety and health duties of employers.	Regulatory	Regulatory	NA	NA	NA	NA	NA
40	US Department of Labor, Occupational Safety and Health Administration, Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute of Occupational Safety and Health. Hospital Respiratory Protection Program Toolkit: Resources for Respirator Program Administrators. May 2015. Occupational Safety and Health Administration. https://www.osha.gov/Publications/OSHA3767.pdf. Accessed September 21, 2016.	Guidance with recommendations and descriptions of mandatory safety and health standards and resources specific to respiratory protection.	VA	Expert Opinion		NA	NA	NA	Respiratory protection
41	Eickmann U, Falcy M, Fokuhl I, Rüegger M, Bloch M, Merz B. Surgical Smoke: Risks and Preventive Measures. Hamburg, Germany: International Social Security Association Section on Prevention of Occupational Risks in Health Services; 2011.	Review of the composition and sources of surgical smoke with strategies to minimize health risks of smoke inhalation. All workers should be aware of the hoards of surgical smoke and preventative measures implemented.	VA	Organizational experience	Health care worker	NA	NA	NA	Exposure facts and interventions to minimize exposure

42	HHE report no. HETA-85-126-1932. Bryn Mawr Hospital, Bryn Mawr, Pennsylvania. September 1, 1988. National Institute for Occupational Safety and Health. http://www.cdc.gov/niosh/nioshtic-2/00184451.html. Accessed September 21, 2016.	Report from surgeons about emissions generated by electrocautery knives when performing reduction mammoplasty. Several operating room personnel were experiencing acute health effects during this procedure, which included respiratory and eye irritation, headache, and nausea.	VA	Case report	OR personnel	NA	NA	NA	Symptoms associated with exposure to surgical smoke
43	Petrus M, Bratu AM, Patachia M, Dumitras DC. Spectroscopic analysis of surgical smoke produced in vitro by laser vaporization of animal tissues in a closed gaseous environment. Romanian Reports in Physics. 2015;67(3):954-965.	The researchers demonstrated the presence of six toxic gases including an average concentrations of acetonitrile (190 ppm), acrolein (35 ppm), ammonia (25 ppm), benzene (20 ppm), ethylene (0.41 ppm), and toluene (45 ppm) in the smoke samples. The results show that the laser vaporization power and the exposure time are important parameters and gas concentrations are influenced by the water content of tissues.	IIA	Quasi-experimental	Fresh animal tissues	CO2 laser	Laser power, exposure time and type of tissue on gas concentrations	4 with multiple measurements	Chemical composition of surgical smoke , specifically: acetonitrile, acrolein, ammonia, benzene, ethylene and toluene
44	Petrus M, Matei C, Patachia M, Dumitras DC. Quantitative in vitro analysis of surgical smoke by laser photocoustic spectroscopy. J Optoelectron Adv M. 2012;14(7- 8):664-670.	Trace amounts of toxic byproducts (eg, benzene, ethylene, ammonia, methanol) were found in the plume produced by the surgical plume. The samples consisted mostly of carbon dioxide and water vapors. Although the concentrations are lower than the recommended values, consideration should be given to the cumulative effect of all volatile compounds relapsed during laser surgery. With continuous exposure the inhalation of surgical smoke becomes more harmful to the surgical team.	IIA	Quasi-experimental	Fresh animal tissues	CO2 laser	Laser power, exposure time and type of tissue on gas concentrations	12	Levels of benzene, ethylene, ammonia, and methanol

45	Sagar PM, Meagher A, Sobczak S, Wolff BG. Chemical composition and potential hazards of electrocautery smoke. Br J Surg. 1996;83(12):1792.	Benzene, ethyl benzene, styrene, carbon disulfide, and toluene were found to be significant in concentration in the smoke produced by electrocautery of the tissue. Additional studies are needed to determine the extent of exposure of all OR personnel and to develop methods to reduce health risks.	IIB	Quasi-experimental	Colorectal surgical patients	Electrocautery with smoke evacuation	Electrocautery smoke emission vs content emission produced by turning on the electrocautery pencil without tissue cauterization	6	Chemical composition of smoke
46	Weston R, Stephenson RN, Kutarski PW, Parr NJ. Chemical composition of gases surgeons are exposed to during endoscopic urological resections. Urology. 2009;74(5):1152-1154.	High levels of carbon monoxide and a cocktail of volatile organic hydrocarbons some of which are carcinogens. Urologists should use smoke evacuators to minimize exposure of inhalation of toxic byproducts contained in surgical plume. Additional research is needed to investigate long-term complications.	IIB	Quasi-experimental study	Urology patients	Electrocauterization and bipolar	Mean concentration of chemical found in the smoke from transurethral resection of the prostate compared to transurethral vaporization of the prostate	4	Chemical analysis of the byproducts of surgical plume and CO level analysis with a portable catalytic flammable gas sensor

47	Zhao C, Kim MK, Kim HJ, Lee SK, Chung YJ, Park JK. Comparative safety analysis of surgical smoke from transurethral resection of the bladder tumors and transurethral resection of the prostate. Urology. 2013;82(3):744. e9-744.e14.	Various types of gases are generated during electrosurgery. Extremely flammable gases were generated in both procedures-transurethral resection of bladder tumor and transurethral resection of the prostate . There were differences in the types of gases generated from the tissues of transurethral resection of bladder tumor (TURB) and transurethral resection of the prostate (TURP). Known carcinogens, including: human carcinogens include 1,3-butadiene, vinyl acetylene, ethyl acetylene, and acrylonitrile in the group I (TURP)and pentafluoroethane, acetaldehyde, benzene, toluene, ethylbenzene, and o-xylene in the group II (TURB). Electrosurgery of malignant tissue is possibly more hazardous to the surgical team. To prevent inhalation of surgical smoke continuous irrigation and suction is needed. Surgical masks	IIB	Quasi-experimental	Surgical patients for TURP and TURB procedures	Resectoscope with cutting loop using an electrosurgical generator	Procedures (1 TURP and 1 TURB) AND malignant tissue vs hypertrophic tissue of the prostate	36 patients in 2 groups (TURB and TURP); 18 patients in each group	Qualitative and quantitative chemical analysis of surgical smoke
48	Bratu AM, Petrus M, Patachia M, et al. Quantitative analysis of laser surgical smoke: targeted study on six toxic compounds. Rom Journ Phys. 2015;60(1-2):215-227.	Acetonitrile, acrolein, ammonia, and benzene exceeding the occupational exposure limits were found in the surgical smoke produced by laser vaporization of animal tissues.	IIA	Quasi-experimental	Animal tissue samples	CO2 Lasers at different photoacoustic levels	Type of tissue, laser power and exposure time	24	Quantitative composition of surgical smoke
49	Lippert JF, Lacey SE, Jones RM. Modeled occupational exposures to gas-phase medical laser-generated air contaminants. J Occup Environ Hyg. 2014;11(11):722-727.	Values of laser-generated air contaminants do not appear to present an occupational exposure hazard within the conditions of the researchers' emission rate estimates. The concentrations of all contaminants were higher in the near-field compared to the far-field.	IIA	Quasi-experimental study	Porcine tissue	Holmium:YAG and CO2 laser application	Two-zone model with the near-field zone including the point of laser generated air contaminants and the laser operator's breathing zone and the far-field zone represents the remainder of the room.	2	Concentration of laser-generated air contaminants

50	Fitzgerald JE, Malik M, Ahmed I. A single-blind controlled study of electrocautery and ultrasonic scalpel smoke plumes in laparoscopic surgery. Surg Endosc. 2012;26(2):337-342.	Electrocautery and ultrasonic dissection devices are significantly associated with lesser carcinogenic and toxic smoke content when compared to cigarette smoke. Long-term exposure warrants respiratory protection and with long-term exposure, the ultrasonic device produces less harmful smoke than the electrocautery device.	IIA	Quasi-experimental, controlled-comparative study	Surgical patients	Electrocautery and ultrasonic tissue dissection	electrocautery and ultrasonic devices	10	Smoke plume quantity and quality
51	Shewale SB, Briggs RD. Gas chromatography-mass spectroscopy analysis of emissions from cement when using ultrasonically driven tools. Acta Orthopaedica. 2005;76(5):647-650.	Toxins found in the ultrasonic plume included: benzene, styrene, methyl methacrylate, xylene, toluene, isopropyl alcohol and dichlorobenzene were some of the substances isolated in the laboratory. Styrene and methyl methacrylate were the main components. Concentrations of all the above components taken from the breathing zone in the operating room staff were well below set safety levels. Ultrasonic instruments for cement removal seem to be safe for use in the OR. The authors concluded that the fumes produced during the use of ultrasonically driven tools for cement removal are safe to the OR team.	IIB	Quasi-experimental study	Revision total hip replacement with cement removal	Ultrasonic system for cemented arthroplasty revisions	Part A-4 different types of cement with and without antibiotics; Part B- air samples from the breathing zone of the surgeon, assistant, scrub nurse, & anesthetist	2	Part A- Plume chemical composition; Part B- Concentrations of methyl methacrylate and styrene

52	Dobrogowski M, Wesolowski W, Kucharska M, et al. Health risk to medical personnel of surgical smoke produced during laparoscopic surgery. Int J Occup Med Environ Health. 2015;28(5):831-840.	The concentrations of toxic substances found in smoke are much lower than standards set by the European Union Maximum Acceptable Concentration (MAC). The calculated risk of developing cancer as a result of exposure to surgical smoke during laparoscopic cholecystectomy is negligible. Repeated exposure to a mixture of these substances increases the possibility of developing adverse effects. Compounds are toxic, carcinogenic, mutagenic, or genotoxic. It is necessary to evacuate surgical smoke.	III B	Non-experimental	Laparoscopic cholecystectomy patients	Air sampling of surgical smoke	NA	20	Surgical smoke components
53	NIOSH Health Hazard Evaluation Report: HETA-2000-0402-3021. Inova Fairfax Hospital, Falls Church, Virginia. November 2006. National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/2000-0402-3021.pdf. Accessed September 21, 2016.	Report from surgery department employees in regard to exposure to compounds found in surgical smoke and respiratory symptoms and headaches thought to be associated with such exposure	VA	Case report	Surgery department workers	NA	NA	NA	Symptoms associated with exposure to surgical smoke
54	NIOSH Health Hazard Evaluation Report: HETA-2001-0066-3019. Morton Plant Hospital, Dunedin, Florida.October 2006. National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/2001-0066-3019.pdf. Accessed September 21, 2016.	Report of concerns from surgery department employees about possible health effects from exposure to byproducts of surgical smoke in the operating room	VA	Case report	Surgery department workers	NA	NA	NA	Personal breathing zone samples and employee symptoms

55	Lin YW, Fan SZ, Chang KH, Huang CS, Tang CS. A novel inspection protocol to detect volatile compounds in breast surgery electrocautery smoke. J Formosan Med Assoc. 2010;109(7):511-516.	Toluene was identified in all radical mastectomy procedures. Toluene concentrations apparently exceeded the Agency for Toxic Substance and Disease Registry minimal risk levels. Length of electrocautery use, surgery type, and patient body mass index are factors that can alter the production of chemicals and should be considered when assessing the smoke exposure risk of the perioperative team. Additional studies are needed to determine long-term health effects from low level exposures.	IIIB	Non-experimental	Patients undergoing breast surgery	Monopolar electrocautery	NA	5	Quantify potentially hazardous chemicals in the electrocautery generated surgical smoke that are inhaled. Second aim was to characterize the factors affecting the production of chemicals in electrocautery generated surgical smoke.
56	NIOSH Health Hazard Evaluation Report: HETA-2001-0030-3020. Carolinas Medical Center, Charlotte, North Carolina. November 2006. National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/2001-0030-3020.pdf. Accessed September 21, 2016.	Report of concerns from surgery department employees in regard to exposure to surgical smoke and symptoms of allergies, respiratory irritation, nausea, and autoimmune disorders reportedly associated with exposure in the operating room. The report was followed by organizational investigation and change.	VA	Organizational experience/Case Report	NA	NA	NA	15 procedures	Management feedback, employee symptoms, and personal breathing zone samples

57	Wu YC, Tang CS, Huang HY, et al. Chemical production in electrocautery smoke by a novel predictive model. Eur Surg Res. 2011;46(2):102-107.	The first theater-based study statistically verifying the effects of surgery type, patient demographics, electrocautery duration and imparted energy on smoke compositions and compositions. Analytical findings indicate the any increase in electrocautery energy, electrocautery duration and patient age is associated with increased toluene production in the surgical smoke for the same type of surgery. Either smoke evacuation or appropriate respiratory protection should be used to provide a healthy work environment.	IIB	Quasi-experimental study	Patients undergoing mastectomy or abdominal cavity surgeries	Electrocautery	Relationship between chemical production and possible influential factors such as surgery type, imparted energy for cutting and coagulation, electrocautery duration, and BMI	30	Analysis and concentrations of ethyl benzene, phenol, styrene, toluene, xylene isomers in surgical smoke
58	Al Sahaf OS, Vega-Carrascal I, Cunningham FO, McGrath JP, Bloomfield FJ. Chemical composition of smoke produced by high-frequency electrosurgery. Ir J Med Sci. 2007;176(3):229-232.	The study demonstrated the presence of irritant, carcinogenic, and neurotoxic compounds in electrosurgical smoke. Thermal decomposition of adipose tissue produced greater quantities of aldehydes and lower concentrations of toluene. The surgical smoke from epidermal tissue had higher levels of toluene, ethyl benzene, and xylene. The results demonstrate considerable implications for the health and safety of all involved as exposure to these compounds pose a potential health risk.	IIB	Quasi-experimental study	Surgical patients	Electrosurgery	Compounds in surgical smoke from 3 types of procedures (ie, verruca extraction, pilonidal sinus removal, abdominal surgery)	13	Chromatographic profiles

59	Choi SH, Kwon TG, Chung SK, Kim TH. Surgical smoke may be a biohazard to surgeons performing laparoscopic surgery. Surg Endosc. 2014;28(8):2374-2380.	For five carcinogenic compounds detected, the cancer risk was greater than negligible. For 1,2-dichloroethane and benzene, the risk was classified as unacceptable. Analysis of noncarcinogenic compounds showed that risk reduction measures are needed for benzene.	IIB	Quasi experimental	Patients undergoing transperitoneal laparoscopic nephrectomy for renal cell carcinoma	CO2 laser vaporization	Surgical smoke samples to Japanese indoor air standards mix	20	Calculated cancer risk and calculated hazardous quotient
60	Krones CJ, Conze J, Hoelzl F, et al. Chemical composition of surgical smoke produced by electrocautery, Harmonic scalpel, and argon beaming—a short study. Eur Surg. 2007;39(2):118-121.	Surgical smoke contains toxic, partly cancerogenic compounds. Concentrations estimated for daily routine are probably below relevant health risk. The exposure to surgical smoke should be minimized, but further clinical research needs to be conducted.	IIA	Quasi-experimental	Porcine tissue	Tissue ablation	The collected aerosols from electrocautery, harmonic scalpel, and argon beaming were analyzed using gas chromatography coupled with mass spectrometry for acrylamide, aldehydes, ketones, volatile and semi-volatile organic compounds, and polycyclic aromatic hydrocarbons.	7	Toxins and carcinogens in aerosol byproduct of surgical smoke
61	Moot AR, Ledingham KM, Wilson PF, et al. Composition of volatile organic compounds in diathermy plume as detected by selected ion flow tube mass spectrometry. ANZ J Surg. 2007;77(1-2):20-23.	Hydrogen cyanide (3–51 parts per million), acetylene (2–8 parts per million), and 1,3-butadiene (0.15–0.69 parts per million were identified in the plume produced by diathermy of tissue. Lack of evidence of the adverse health effects from the volatile organic compounds in surgical smoke and also there is a lack of evidence of the safety of breathing surgical smoke. Recommended use of smoke evacuators to minimize exposure risk to harmful chemicals produced by diathermy.	IIB	Quasi-experimental	Tissue of patients undergoing abdominal surgery	Diathermy	Air samples of suction contents immediately before electrocautery and suction contents during electrocautery of abdominal tissue	12	Volatile organic compound composition

62	Tseng HS, Liu SP, Uang SN, et al. Cancer risk of incremental exposure to polycyclic aromatic hydrocarbons in electrocautery smoke for mastectomy personnel. World J Surg Oncol. 2014;12:31.	Submicron particles in electrocautery smoke contain carcinogenic chemicals. More than 70% of electrocautery smoke from mastectomy patients were smaller than 0.3 microns, an indication that the particles my harm the health of surgical personnel through respiration. This study estimates the average cancer risk in a 70-year lifetime for a surgeon was estimated to be 117×10^{-6} and for anesthesia providers to be 270×10^{-6}. The use of an effective smoke evacuator is strongly suggested to diminish the hazards to surgical staff	IIB	Quasi experimental	Mastectomy patients	Electrocautery	The particle number concentration and gaseous/particle polycyclic aromatic hydrocarbons at the surgeon's and anesthesia provider's breathing heights measured with a particle counter and filter/adsorbent samplers	10	Particle number concentration and concentrations of polycyclic aromatic hydrocarbons in electrocautery smoke gaseous/particle PAHs at the surgeons 'and anesthetic technologists'(AT) breathing heights
63	Näslund Andréasson S, Mahteme H, Sahlberg B, Anundi H. Polycyclic aromatic hydrocarbons in electrocautery smoke during peritonectomy procedures. J Environ Public Health. 2012;2012:929053.	Low levels of polycyclic aromatic hydrocarbons were detected in electrocautery smoke during peritonectomy procedures, and an increased amount of bleeding correlated with higher levels of polycyclic aromatic hydrocarbons(PAHs). Long-term exposure to PAHs could lead to high cumulative levels in surgeons and OR personnel and the simultaneous exposures to particles, PAHs, and volatile organic compounds may have synergistic and additive effects. More studies are needed to evaluate the long-term health effects.	IIA	Quasi-experimental	Peritonectomy surgery	electrocautery	Measurement of polycyclic aromatic hydrocarbons in personal and stationary sampling devices	40	Identification and quantification of polycyclic aromatic hydrocarbons in surgical smoke

64	HHE report no. HETA-88-101-2008. University of Utah Health Sciences Center, Salt Lake City, Utah. February 1990. National Institute for Occupational Health and Safety. https://www.cdc.gov/niosh/hhe/reports/pdfs/1988-0101-2008.pdf. Accessed September 21, 2016.	Report received of possible hazardous exposures to smoke generated by medical lasers during laser surgery and animal research procedures. Detectable levels of ethanol, isopropanol, anthracene, formaldehyde, cyanide, and airborne mutagenic substances were recorded as potential health hazards.	VA	Case report	OR personnel	NA	NA	NA	Toxins and carcinogens in aerosol byproduct
65	Beebe DS, Swica H, Carlson N, Palahniuk RJ, Goodale RL. High levels of carbon monoxide are produced by electro-cautery of tissue during laparoscopic cholecystectomy. Anesth Analg. 1993;77(2):338-341.	Peritoneal carbon dioxide levels were higher than recommended; however, there was no evidence of significant absorption of carbon monoxide. Care should be exercised to evacuate the gases produced by electrocautery to avoid OR contamination during laparoscopic surgery.	IIB	Quasi experimental	Laparoscopic cholecystectomy patients	Electrocautery	Carboxyhemoglobin levels at the beginning of surgery, end of surgery, and day after surgery.	9	Levels of carbon monoxide in the insufflation gas and blood levels of carboxyhemoglobin
66	Fan JK, Chan FS, Chu KM. Surgical smoke. Asian J Surg. 2009;32(4):253-257.	A surgical mask can provide more than 90% protection to exposure to surgical smoke, but does not provide protection from ultrafine particles and a tight fit is not always possible. A N95 grade or equivalent respirator offers the best protection against surgical smoke. It is unknown if a level as of protection as high as a N95 is necessary.	VA	Literature review	NA	NA	NA	NA	Review of literature on surgical smoke
67	Andréasson SN, Anundi H, Sahlberg B, et al. Peritonectomy with high voltage electrocautery generates higher levels of ultrafine smoke particles. Eur J Surg Oncol. 2009;35(7):780-784.	High-voltage peritonectomy produces elevated levels of ultrafine particles, similar to the smoke produced by cigarettes. Smoke evacuators must be used to minimize risk of exposure to patients and OR personnel.	IIB	Quasi-experimental-cohort comparison study	Colorectal and peritonectomy surgical patients	Electrosurgery	Peritonectomy and standard colon surgery and personal samples versus stationary samples	25	Amount of airborne and ultrafine particles

68	Taravella MJ, Viega J, Luiszer F, et al. Respirable particles in the excimer laser plume. J Cataract Refract Surg. 2001;27(4):604-607.	The plume created during excimer laser ablation of the cornea contained respirable-size particles. It is unknown whether inhalation of these particles poses a significant health hazard. The authors recommend that a mask be worn by the surgeon and technical personnel assisting in excimer laser surgery. Additionally, the plume should be evacuated.	IIB	Quasi-experimental study	Eye-bank corneas	Excimer laser ablation	Control of room air versus collected plume from the smoke evacuator	2	Presence of respirable-size particles in the excimer laser plume following ablation of the corneal stroma
69	Pierce JS, Lacey SE, Lippert JF, Lopez R, Franke JE. Laser-generated air contaminants from medical laser applications: a state-of-the-science review of exposure characterization, health effects, and control. J Occup Environ Hyg. 2011;8(7):447-466.	Protective precautions must be taken to minimize the risk of surgical smoke exposure to OR personnel, as the use of laser technologies and applications are anticipated to increase. Additional laboratory studies are needed to systematically account for the variables that influence exposure, followed by a broader assessment of exposure to laser generated air contaminant in the clinical setting.	VB	Literature review	NA	NA	NA	NA	Hazard of surgical smoke
70	Bruske-Hohlfeld I, Preissler G, Jauch KW, et al. Surgical smoke and ultrafine particles. J Occup Med Toxicol. 2008;3:31.	There is short term very high exposure to ultrafine particles for surgeons and close assisting personnel alternating with longer periods of low exposure.	IIB	Quasi-experimental study	Surgical procedures	Condensation particle counter	Different types of surgical procedures	6	Particle number concentration
71	DesCoteaux JG, Picard P, Poulin EC, Baril M. Preliminary study of electrocautery smoke particles produced in vitro and during laparoscopic procedures. Surg Endosc. 1996;10(2):152-158.	This study demonstrates the presence of breathable aerosols and cell-size fragments in the cautery smoke produced during laparoscopic procedures. Their exact chemical composition and potential adverse effects for patients and personnel are not known.	IIB	Quasi-experimental	Laparoscopic surgery patients and animal tissue	Electrocautery	In vivo and in vitro smoke particles	8	Morphology, size, and elemental composition of smoke particles produced during laparoscopic procedures

72	Farrugia M, Hussain SY, Perrett D. Particulate matter generated during monopolar and bipolar hysteroscopic human uterine tissue vaporization. J Minim Invasive Gynecol. 2009;16(4):458-464.	Electrosurgical vaporization of tissue during hysteroscopy using a monopolar device produces particles smaller in diameter when compared to the particles produced using a bipolar device.	IIA	Quasi-experimental	Hysteroscopy patients' tissue	Electrosurgery	Monopolar device vs bipolar device	8 patients' tissue samples	Insoluble particulate matter
73	Wang HK, Mo F, Ma CG, et al. Evaluation of fine particles in surgical smoke from an urologist's operating room by time and by distance. Int Urol Nephrol. 2015;47(10):1671-1678.	The concentration of fine particles can reach unhealthy levels particularly for the personnel nearest the incision. Smoke evacuation is needed from the beginning of surgery. Wall suction may not be effective in evacuating the smoke. The OR team should be aware of the potential hazards and take preventative measures to minimize their exposure to fine particles.	IIB	Quasi-experimental study	Patients undergoing superficial, open abdominal, laparoscopic surgeries, open pelvic surgeries and transurethral urology surgeries	Bipolar electrocautery for open and laparoscopic surgeries and electrosurgical resectoscope for the transurethral surgeries.	Amount of fine particles generated during superficial, open abdominal, open pelvic surgeries and transurethral urology surgeries by time and distance	25	Analysis of the amount of fine particles generated in different urological surgeries.
74	Lopez R, Lacey SE, Jones RM. Application of atwo-zone model to estimate medical laser-generatedparticulate matter exposures. J Occup Environ Hyg.2015;12(5):309-313.	The researchers modeled an estimated range of occupational exposure to laser generated particulate matter for health care workers involved in medical laser procedures. The results were within the range of concentrations measured in limited field studies in hospital ORs. As technologies evolve, the modeling can be used to estimate potential exposure.	IIB	Quasi-experimental	Porcine tissue	CO2 laser application	Two-zone model with the near-field zone including the procedure site and the laser operator's breathing zone and the far-field zone represents the remainder of the room.	2	Estimated concentrations of respirable laser generated particulate matter

75	Lopez R, Lacey SE, Lippert JF, Liu LC, Esmen NA, Conroy LM. Characterization of size-specific particulate matter emission rates for a simulated medical laser procedure—a pilot study. Ann Occup Hyg. 2015;59(4):514-524.	All of the factors examined were influential in the generation of particulate matter during laser procedures. Further refinement of parameters to determine clinical procedures and laser device settings that produce the greatest exposure risks. Communicating the risks to clinicians and the occupational hygiene community will increase awareness and lead to improved control strategies that minimize or eliminate surgical smoke exposure.	IIIA	Non-experimental	Porcine tissue	Holmium:YAG and CO2 laser application varying three operational parameters of beam diameter, pulse repetition frequency and power.	Three laser parameters of power, beam diameter, and pulse repetition of the Holmium:YAG and CO2 lasers	8	Influence of operational parameter settings on size-specific mass emission rate
76	Benson SM, Novak DA, Ogg MJ. Proper use of surgical N95 respirators and surgical masks in the OR. AORN J. 2013;97(4):457-467.	During smoke generating procedures, if the healthcare worker can smell the smoke, potentially dangerous and infectious debris and contaminants are being released into the atmosphere. The debris can cause adverse health effects. Respiratory PPE is the last line of defense against surgical smoke. The individual should know when and how to use a respirator properly.	VA	Literature review	NA	NA	NA	NA	NA
77	Ragde SF, Jorgensen RB, Foreland S. Characterisation of exposure to ultrafine particles from surgical smoke by use of a fast mobility particle sizer. Ann Occup Hyg. 2016;60(7):860-874.	The use of electrocautery resulted in short-term high peak exposures to mainly ultrafine particles. The exposure to ultrafine particles (UFPs) was highest during abdominoplasty and lowest during hip replacement surgeries. The different job groups had similar exposure during the same types of surgical procedures. Type of surgery was the strongest predictor of exposure and different types of surgery produced different sized particles.	IIIA	Non-experimental	OR personnel	Use of electrosurgery	Five different types of surgical procedures (ie, hip replacement, nephrectomy, breast reduction, abdominoplasty, transurethral urologic resection)	48 personal particle exposures	Ultrafine particles and particle size distribution

78	Brace MD, Stevens E, Taylor SM, et al. "The air that we breathe": assessment of laser and electrosurgical dissection devices on operating theater air quality. J Otolaryngol Head Neck Surg. 2014;43(1):39-57.	OR air contains particles that are smaller than outdoor air. Lasers produce higher particle counts that have coarse properties, while electrocautery produces ultrafine particles. Until there is additional research, surgical masks with ultrafine	IIA	Non-experimental-descriptive,	OR environment (rooms and hallways)	Air quality monitoring	OR and hallway air quality measurements of particulate matter concentrations, ultrafine particles, and course particles, temperature, relative humidity, and CO2 and outdoor air quality measurements.	90 surgical cases	Air quality during surgery
79	Norris BK, Goodier AP, Eby TL. Assessment of air quality during mastoidectomy. Otolaryngol Head Neck Surg. 2011;144(3):408-411.	The concentration of bone dust produced during cortical mastoidectomy is below regulatory guidelines for use of particulate respirators. Experimental studies demonstrate the use of a surgical respirator may decrease particulate exposure. Healthcare workers should be aware of the potential risks of bone dust exposure during otologic surgeries.	IIB	Quasi-experimental	Cadaveric temporal bones	Mastoidectomy with a high-speed electric drill at 80,000 RPM for 20 minutes	Standard surgical mask, surgical respirator, and control	3 trials	Air quality by quantifying the total suspended particulate exposure and respirable particulate matter

80	Ziegler BL, Thomas CA, Meier T, Müller R, Fliedner TM, Weber L. Generation of infectious retrovirus aerosol through medical laser irradiation. Lasers Surg Med. 1998;22(1):37-41.	Viruses in laser vapors remain infectious and remain capable of integrating into the genome of susceptible cells. Laser vapors may also contain partially inactive and incompetent viruses. A possible explanation is that the direct impact of laser beams may cause fragmentation of some viruses that are rendered non-infectious. Partial or oncogene sequences can also pose a significant health risk for exposed Team members since they may have transforming potential. The findings suggest the possibility that laser used during tumor surgery may contribute to the dissemination of tumor cells and promote local or distant metastasis. Lasers may pose a significant biohazard to the healthcare team.	IIB	Quasi-experimental study	Laser treated retrovirus supernatant and wild-type NIH3Ts cells.	Er:YAG Laser Beam	Infectious viral particles, viral mRNA, and viable cells in laser vapors at 12 distance points ranging from 0.7 cm- 11.8 cm from laser impact .	2	Detection and quantitation of infectious viral particles, viral mRNA, and viable cells in laser vapors
81	Garden JM, Kerry O'Banion M, Bakus AD, Olson C. Viral disease transmitted by laser-generated plume (aerosol). Arch Dermatol. 2002;138(10):1303-1307.	Laser plume transmits disease. Laser practitioner must minimize potential health risks especially when treating viral-induced lesions or patients with viral disease.	IIB	Quasi-experimental	Bovine calves	Injection of bovine papilloma virus-induced cutaneous fibropapillomas exposed to CO2 laser	Development of tumors	3	Laser plume viral content and post inoculation tumor growth analysis and documentation

82	Price JA, Yamanashi W, McGee JM. Bacteriophage phi X-174 as an aerobiological marker for surgical plume generated by the electromagnetic field focusing system. J Hosp Infect. 1992;21(1):39-50.	Surgical plume was seen and documented by the recovery of the virus. This indicates the need for a vacuum device to collect the air from the surgical field. Set power had little observed effect on plume generation at normal operational levels but the way the power was delivered did modulate surgical plume. This suggests that perhaps for cautery devices in general there may be more of a smoke hazard associated with cautery than cutting. Results reinforce the need for smoke evacuation during aerosol generating procedures and the surgical smoke biohazard may vary with surgical method depending on the device.	IIB	Quasi-experimental	Variant of bacterial virus phi X-174	Use of the electromagnetic field focusing system	Parameters (eg, cutting, coagulation) which effect the generation of surgical plume with the use of the electromagnetic field focusing system.	4	Surgical smoke virus penetration
83	Matchette LS, Faaland RW, Royston DD, Ediger MN. In vitro production of viable bacteriophage in carbon dioxide and argon laser plumes. Lasers Surg Med. 1991;11(4):380-384.	Plume-borne viable phage were observed to be associated with particles large enough to settle out from the surgical smoke within 100 mm of the beam impact site. The ratio of the number of dispersed viable phage compared to the number of viable phage dispersed by a single, one second laser exposure was on the order of 10^{-6} to 10^{-10}	IIB	Quasi-experimental study	Bacteriophage Phi X174 as a model for submicron sized viruses such as HIV and HPV	Laser beam	CO2 laser and argon laser	29	Smoke plume bacteriophage production
84	Matchette LS, Vegella TJ, Faaland RW. Viable bacteriophage in CO2 laser plume: aerodynamic size distribution. Lasers Surg Med. 1993;13(1):18-22.	The presence of viable bacteriophage in the plume produced by a CO2 laser is a rare occurrence. Viable bacteriophage that are produced by CO2 lasers are large in size.	IIB	Quasi-experimental study	Bacteriophage Phi X174 as a model for virus-containing tissue	CO2 laser beam	Two models of a six-stage bioaerosol cascade impactors	6	Bacteriophage presence and size in smoke plume

85	Taravella MJ, Weinberg A, May M, Stepp P. Live virus survives excimer laser ablation. Ophthalmology. 1999;106(8):1498-1499.	Oral polio vaccine virus can survive excimer laser ablation. Their investigation proved that at least one type of virus can remain infectious after undergoing laser ablation. It is undetermined whether other more clinically relevant viruses, such as human immunodeficiency virus, can withstand ablation and remain infectious. The authors recommend treating the laser plume as biohazardous waste and to exercise precautions such as wearing a mask that can filter small particles and evacuating the plume.	IIB	Quasi-experimental study	Fibroblasts infected with oral polio vaccine virus	Excimer laser ablation	Control-collection of plume 1 cm from the surface of the plates containing the virus without ablation versus collection of the plume during excimer laser ablation	12	Survivability of a live virus after exposure to the excimer laser and health hazard to medical personnel
86	Ediger MN, Matchette LS. In vitro production of viable bacteriophage in a laser plume. Lasers Surg Med. 1989;9(3):296-299.	Few viable viruses were transported from the ablation site to the agar plate in the byproduct produced by the Er:YAG Laser.	IIB	Quasi-experimental	NA	Er:YAG Laser Beam	Time and number of laser pulses	14	Viable virus
87	Mellor G, Hutchinson M. Is it time for a more systematic approach to the hazards of surgical smoke?: reconsidering the evidence. Workplace Health Saf. 2013;61(6):265-270.	The literature provides a great deal of information about the health hazards of surgical smoke including exposure to hazardous chemicals, whole cells, and bacterial and viral particles. Additional investigation and research is needed on the short- and long-term exposure levels, composition of surgical smoke produced by different electrosurgical techniques, and the impact of air exchanges in the OR.	IIA	Systematic review	NA	NA	Hazardous substances in surgical smoke	42 Research studies	Health hazard(s) of surgical smoke

88	Sood AK, Bahrani-Mostafavi Z, Stoerker J, Stone IK. Human papillomavirus DNA in LEEP plume. Infect Dis Obstet Gynecol. 1994;2(4):167-170.	Eighty percent of the tissue samples were positive for HPV. HPV DNA was present in 37% of the filters. The plume of smoke generated by loop electrosurgical excision procedure (LEEP) may become contaminated by HPV DNA. It is unclear whether the HPV DNA is viable. Since the consequences of HPV in LEEP plume are unknown, it is recommended to reduce the risk of potential infection to the patient, surgeon, and OR team, PPE and smoke evacuation is used.	IIB	Quasi-experimental	Patients with cervical neoplasia	Loop electrosurgical excision procedure	Correlation of tissue samples, filters, and HPV DNA positivity	49	Presence of viable HPV DNA
89	Andre P, Orth G, Evenou P, Guillaume JC, Avril MF. Risk of papillomavirus infection in carbon dioxide laser treatment of genital lesions. J Am Acad Dermatol. 1990;22(1):131-132.	HPV-6 was detected in the specimens and the surgical plume of 2 out of 3 patients in the study. Potential viral contamination through the smoke of CO2 laser-treated lesions is important because certain HPV types are associated with the development of pre-malignant lesions and invasive carcinoma.	IIB	Quasi-experimental, cohort study	Patients with genital condylomata	CO2 laser vaporization	Presence of HPV-6 in the biopsy specimen and surgical plume	3	HPV-6 DNA
90	Ferenczy A, Bergeron C, Richart RM. Carbon dioxide laser energy disperses human papillomavirus deoxyribonucleic acid onto treatment fields. Am J Obstet Gynecol. 1990;163(4 Part 1):1271-1274.	CO2 laser energy disperses HPV DNA onto treatment fields and the adjacent normal epithelium. Viral contamination of treated areas may be reduced by positioning the fume evacuator within 1 cm of the field of laser vaporization and cleaning the treated areas and surrounding tissue after therapy.	IIB	Quasi experimental	Adults with HPV genital warts	CO2 laser vaporization	Tissue swab before and after laser vaporization; contents of surgical smoke	43	HPV DNA on mucosa and in surgical smoke

91	Ferenczy A, Bergeron C, Richart RM. Human papillomavirus DNA in CO2 laser-generated plume of smoke and its consequences to the surgeon. Obstet Gynecol. 1990;75(1):114-118.	Human papillomavirus DNA was identified in swabs from 65 of 110 (60%) of histologically unequivocal condylomata and cervical intraepithelial neoplasia. Contamination of the laser operator with HPV during the ablation of HPV-containing tissue is highly unlikely with the use of appropriate smoke evacuation equipment.	IIB	Quasi experimental	Patients undergoing ablation of HPV-containing genital warts	Laser ablation of HPV-containing genital tissue	NA	110	Viable HPV
92	Kashima HK, Kessis T, Mounts P, Shah K. Polymerase chain reaction identification of human papillomavirus DNA in CO2 laser plume from recurrent respiratory papillomatosis. Otolaryngol Head Neck Surg. 1991;104(2):191-195.	When HPV was identified in the smoke vapor, the same HPV type was identified in the corresponding tissue sample. HPV in the smoke vapor raises concern regarding the risk from smoke exposure to the surgeon and OR team.	IIB	Quasi-experimental	Patients undergoing CO2 laser excision of laryngeal lesions	CO2 laser excision	Presence of HPV in the smoke vapor and corresponding tissue samples.	22	HPV
93	Sawchuk WS, Weber PJ, Lowy DR, Dzubow LM. Infectious papillomavirus in the vapor of warts treated with carbon dioxide laser or electrocoagulation: detection and protection. J Am Acad Dermatol. 1989;21(1):41-49.	The risk of papillomavirus infection for laser operators and other personnel can be minimized when proper precautions are taken. Smoke evacuation is the most important precaution, but efficiency drops when the distance increases from the treatment site. The use of properly fitted and tied surgical masks reduces airway exposure	IIB	Quasi-experimental study	Patients with plantar warts	Treatment with electrosurgery and CO2 laser	HPV DNA in the vapor from electrosurgery treated warts versus laser treated	8	Detection of papillomavirus DNA in the plume from treated human warts
94	Garden JM, O'Banion MK, Shelnitz LS, et al. Papillomavirus in the vapor of carbon dioxide laser-treated verrucae. JAMA. 1988;259(8):1199-1202.	Viral intact DNA is liberated into the air with the vapor of laser-treated verrucae. Laser practitioner must minimize potential health risks especially when treating viral-induced lesions or patients with viral disease.	IIB	Quasi-experimental	Patient with plantar or mosaic verrucae & bovine calves	Injection of bovine papilloma virus-induced cutaneous fibropapillomas exposed to CO2 laser	Development of tumors	Pateints-7; Calves-3	Laser plume viral content and post inoculation tumor growth analysis and documentation

95	Weyandt GH, Tollmann F, Kristen P, Weissbrich B. Low risk of contamination with human papilloma virus during treatment of condylomata acuminata with multilayer argon plasma coagulation and CO2 laser ablation. Arch Dermatol Res. 2011;303(2):141-144.	Both CO2 laser treatment with plume suction and argon plasma coagulation treatment seem to have a low risk of HPV contamination of the operating room when smoke evacuators are used.	IIB	Quasi-experimental study	Patients with genital warts	Multilayer argon plasma coagulation treatment or CO2 laser treatment	HPV DNA in Petri dishes at 1 meter, 2 meter, & overnight after the last treatment of the day; inside the tube of the suction hand piece; and nasolabial folds and glasses of the operating physician before and after multilayer APC treatment.	11	Liberation of HPV DNA during argon plasma coagulation treatment or CO2 laser treatment
96	Baggish MS, Poiesz BJ, Joret D, Williamson P, Refai A. Presence of human immunodeficiency virus DNA in laser smoke. Lasers Surg Med. 1991;11(3):197-203.	The study demonstrated that HIV viral DNA was present in the laser smoke and the cultured cells were PCR positive for proviral DNA. Smoke evacuation must be kept close to the operative field to remove the vapor before it is inhaled by the OR team. Most if not all of the potentially infectious debris will accumulate in the tubing. It should be considered hazardous and disposed of appropriately.	IIA	Quasi-experimental	HIV infected cells	Carbon dioxide laser	Vapor of HIV infected cells versus uninfected HUT 78 cells	2	HIV DNA
97	Johnson GK, Robinson WS. Human immunodeficiency virus-1 (HIV-1) in the vapors of surgical power instruments. J Med Virol. 1991;33(1):47-50.	HIV-1 can remain viable in the cool vapors produced by surgical power instruments and lends the possibility of HIV-1 transmission to healthcare workers.	IIA	Quasi-experimental	Mixture of human blood and tissue cultures with HIV-1	Generation of aerosols with powered surgical instruments	Powered surgical instruments (ie, router, bone saw, irrigator, electrocautery)	NA	Isolation of infectious HIV-1 from aerosols generated from human blood containing HIV-1 by common orthopedic and surgical procedures that cause aerosols.
98	Capizzi PJ, Clay RP, Battey MJ. Microbiologic activity in laser resurfacing plume and debris. Lasers Surg Med. 1998;23(3):172-174.	The potential exists for operating personnel to be exposed to viable bacteria during laser resurfacing procedures	IIC	Quasi-experimental	Laser resurfacing patients	CO2 laser resurfacing	Pre-procedure air filter to two consecutive filters used for 5 minutes each after the resurfacing started	13	Bacterial and viral content

99	McKinley IB Jr, Ludlow MO. Hazards of laser smoke during endodontic therapy. J Endod. 1994;20(11):558-559.	The laser smoke does present a hazard of bacterial dissemination and precautions must be taken to protect against spreading infections when using lasers in the root canal.	IIIB	Non-experimental-descriptive study	Freshly extracted single-rooted teeth	Inoculation of the teeth with *Escherichia coli* followed by argon lasing of the root canals	NA	5 teeth	Potential for spreading bacterial contamination from the root canal to the patient and dental team determined by positive cultures for *Escherichia coli*
100	Nogler M, Lass-Florl C, Wimmer C, Mayr E, Bach C, Ogon M. Contamination during removal of cement in revision hip arthroplasty. A cadaver study using ultrasound and high-speed cutters. J Bone Joint Surg Br. 2003;85(3):436-439.	Environmental contamination was present in an area of 6 x 8 meters for both devices. The concentration of contamination was lower for the ultrasound device. Both the ultrasound and the high-speed cutter contaminated all members of the surgical team. Personal protective equipment of fluid resistant gowns, gloves, and full-face protection with face shields should be mandatory during this type of surgery for all personnel in the OR.	IIA	Quasi-experimental	Surgical personnel during removal of cement in a revision hip arthroplasty & Petri dishes with mannitol salt agar	Removal of bone cement	Ultrasound device and high-speed cutter	4 personnel and 48 Petri dishes with mannitol salt agar	Environmental and body contamination
101	Rautemaa R, Nordberg A, Wuolijoki-Saaristo K, Meurman JH. Bacterial aerosols in dental practice—a potential hospital infection problem? J Hosp Infect. 2006;64(1):76-81.	The results showed significant contamination of the room at all distances sampled when high-speed instruments were used. The bacterial density was found to be higher in the more remote sampling points. Gram-positive cocci, namely viridans streptococci and staphylococci, were the most common findings. The area contaminated is larger than previously thought and practically the entire room is contaminated.	IIIC	Non-experimental	Fallout sample during restorative dentistry procedures	Electric high-speed drill and no drilling	Fallout samples without the use of electric instruments with samples collected in rooms using high-speed rotating instruments, and rooms at rest	99	Contamination of the samples measured by colony forming units
102	Cukier J, Price MF, Gentry LO. Suction lipoplasty: biohazardous aerosols and exhaust mist—the clouded issue. Plast Reconstr Surg. 1989;83(3):494-497.	Viable, intact bacteria remained in the aerosol vapors for three hours after rotary vein aspirator was used. With application of an appropriate filter device, the pump and the environment were protected from viable bacteria.	IIB	Quasi-experimental	Saline suspension of Pseudomonas	Aspiration with a rotary vane aspirator	Aspirator pump with filter and without at 10 minutes, 1 hour, and 3 hours	9	Presence of pseudomonas aeruginosa

103	Schultz L. Can efficient smoke evacuation limit aerosolization of bacteria? AORN J. 2015;102(1):7-14.	The results demonstrated that only blended current electrosurgery, not laser plume or coagulation electrosurgery, contains viable bacteria. Additionally, the study revealed that placing a suction device near the electrosurgical site reduced the number of aerosolized viable bacteria	IIB	Quasi-experimental study	Porcine skin and fat	Coagulation with and without suction using blended electrosurgical current or laser	Bacterial aerosolizaton with blended electrosurgical current, CO2 laser	10	Existence of viable bacteria (*Serratia marcescens)* in surgical smoke; bacterial contamination of wound margins; and elimination of contamination with effective smoke capture
104	Lewin JM, Brauer JA, Ostad A. Surgical smoke and the dermatologist. J Am Acad Dermatol. 2011;65(3):636-641.	A review of the literature on surgical smoke, its effects on those exposed, and measures that may be used to protect dermatologists and their staff. The studies reviewed point to the potential for infection, carcinogenesis, and pulmonary damage as a result of surgical smoke exposure.	VB	Literature review	NA	NA	NA	NA	Hazards of surgical smoke, effects of exposure, and measures to protect dermatologists and staff.
105	Ishihama K, Sumioka S, Sakurada K, Kogo M. Floating aerial blood mists in the operating room. J Hazard Mater. 2010;181(1-3):1179-1181.	High-speed surgical instruments and electrocoagulator devices produce blood mists that can float in the OR. Operating room personnel must use safety measures to prevent inhalation of the particles.	IIC	Quasi experimental	Dental patients	Test filters covering the HVAC exhaust ducts	Level of blood contamination of the test filters after 1, 2, and 4 weeks; level of blood contamination after each surgical procedure	33	Presence of blood-contaminated aerosol in the OR environment.
106	Ishihama K, Koizumi H, Wada T, et al. Evidence of aerosolised floating blood mist during oral surgery. J Hosp Infect. 2009;71(4):359-364.	Blood-contaminated materials have the potential to be suspended in air as blood-contaminated aerosol. The risk of cross-infection at the dental practice for immunocompromised patients and healthy staff exists.	IIB	Quasi experimental	Dental patients	Dental extraction with high speed instruments (eg, dental turbine, air motor, micro-engine hand piece)	Collected aerosols at 20, 60, and 100 cm from the surgical site	132	Existence of floating blood aerosol during dental surgery

107	Jewett DL, Heinsohn P, Bennett C, Rosen A, Neuilly C. Blood-containing aerosols generated by surgical techniques: a possible infectious hazard. Am Ind Hyg Assoc J. 1992;53(4):228-231.	Larger particles were positive for hemoglobin content and were produced by the oscillating bone saw, high-speed irrigating drill and demonstrated no infectivity. Aerosols produced by the Hall Drill demonstrated bimodal distribution pattern. Air mass concentrations generated by the router were the lowest (0.02 to 0.29 1-Lg/L), yet the majority of the cultures (5 of 7) were positive. All of the instrumentation tested produced blood-containing aerosol particles in the respirable range.	IIB	Quasi-experimental	Bovine tissue samples	Surgical techniques with bone saws and drills and electrosurgery	Aerosols generated by an oscillating bone saw, a drill, a high-speed irrigating drill, used on bone, and a electrocautery used in both the cutting and coagulation modes on tendon with blood and distilled water.	25	Particle size distribution representative of blood containing aerosols and hemoglobin content of each particle size fraction.
108	Champault G, Taffinder N, Ziol M, Riskalla H, Catheline JM. Cells are present in the smoke created during laparoscopic surgery. Br J Surg. 1997;84(7):993-995.	The presence of whole identifiable cells carried in the peritoneum is concerning for exposure of the OR staff and re-implantation of tumor cells. No malignant cells were found in the samples.	IIB	Quasi experimental	Laparoscopic surgical patients	Gas used during laparoscopic surgery was filtered followed by washing of the filter and tubing, and then centrifuged.	Metastatic and non-metastatic tumor cells	9	Viable tumor cells
109	Collins D, Rice J, Nicholson P, Barry K. Quantification of facial contamination with blood during orthopaedic procedures. J Hosp Infect. 2000;45(1):73-75.	Power instrumentation produces a blood particulate mist during orthopedic surgery causing considerable microscopic, facial contamination which is a significant risk to the surgeon	IIC	Quasi-experimental study	Acute orthopedic trauma patients	orthopedic power instrumentation and pulse lavage	Amount of blood splatter versus recognition of the splatter by the surgeon	46	Blood splatter & post-operative questionnaire

110	Ott DE, Moss E, Martinez K. Aerosol exposure from an ultrasonically activated (Harmonic) device. J Am Assoc Gynecol Laparosc. 1998;5(1):29-32.	Particle size concentrations created during typical Harmonic scalpel procedures are within the respirable range, are composed of tissue, blood, and blood by-products, and can be present at distances removed from the production site, and that aerosols tend to congregate at a relatively short distance from the device and close to the operator. Local exhaust ventilation should be activated to reduce exposure to blood, blood by-products, and potentially infectious materials,	IIB	Quasi-experimental	Animal tissue, water, blood	Ultrasonic harmonic device with 3 tip configurations of ball, curved scalpel and cutting.	Sampling of airborne aerosols over six-second sampling intervals at different power settings and distances of 5,10,15, and 20 cm from the samples with and without smoke evacuation	4	Airborne aerosol content
111	In SM, Park DY, Sohn IK, et al. Experimental study of the potential hazards of surgical smoke from powered instruments. Br J Surg. 2015;102(12):1581-1586.	Ultrasonic scalpels produce viable cancer cells when used to vaporize or dissect cancerous tissue.	IIA	Quasi-experimental study	Tumor cell lines	Powered surgical instruments-electrocautery, radiofrequency ablation, and ultrasonic scalpels	Various surgical devices to determine whether viable cells exist in surgical smoke *in vitro and in vivo*	65	Viable cells in surgical smoke
112	Mowbray N, Ansell J, Warren N, Wall P, Torkington J. Is surgical smoke harmful to theater staff? A systematic review. Surg Endosc. 2013;27(9):3100-3107.	The potentially carcinogenic components of surgical smoke are sufficiently small to be respirable. Infective and malignant cells are found in the smoke plume, but the full risk of surgical smoke exposure to the OR team is unproven. Additional research could focus on the long-term consequences of smoke exposure.	IIIA	Systematic review	NA	NA	NA	20 studies	Properties of surgical smoke and the evidence of the harmful effects to OR personnel
113	Nahhas WA. A potential hazard of the use of the surgical ultrasonic aspirator in tumor reductive surgery. Gynecol Oncol. 1991;40(1):81-83.	Vapor produced by an ultrasonic aspirator contains viable tumor cells in patients undergoing tumor resection surgery. These viable cells have the potential for transmission to OR personnel.	VA	Case repot	Patients undergoing ovarian cancer surgery	Tumor vaporization with ultrasonic aspirator	NA	2	Presence of numerous fresh, intact and possibly viable cancer cells in the mist collected during the use of ultrasonic aspirator.

114	Pierce JS, Lacey SE, Lippert JF, Lopez R, Franke JE, Colvard MD. An assessment of the occupational hazards related to medical lasers. J Occup Environ Med. 2011;53(11):1302-1309.	The use of medical lasers poses a health and safety threat to healthcare workers particularly the inhalation of laser generated airborne contaminants. Additional research is needed to quantify the risks.	VB	Literature review	NA	NA	NA	NA	Chemical concentrations, size of particulates, and composition of smoke produced by medical lasers during surgery.
115	Control of Smoke from Laser/Electric Surgical Procedures (DHHS [NIOSH] Pub No 96-128). National Institute for Occupational Safety and Health. http://www.cdc.gov/niosh/docs/hazardcontrol/hc11.html. Accessed September 21, 2016.	The hazards of surgical smoke can be controlled with local exhaust ventilation and work practice controls.	IVB	Clinical Practice Guideline	NA	NA	NA	NA	NA
116	Chung YJ, Lee SK, Han SH, et al. Harmful gases including carcinogens produced during transurethral resection of the prostate and vaporization. Int J Urol. 2010;17(11):944-949.	Three of the toxic gases generated during TURP and vaporization are carcinogens (butadiene, vinyl acetylene and acrylonitrile). 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.	IIB	Quasi experimental	TURP patients	Vaporization with resectoscope and cutting loop	NA	12	Chemical composition of surgical smoke
117	Park SC, Lee SK, Han SH, Chung YJ, Park JK. Comparison of harmful gases produced during Green-Light High-Performance System laser prostatectomy and transurethral resection of the prostate. Urology. 2012;79(5):1118-1124.	Harmful byproducts are produced by greenlight laser instrument in patients undergoing transurethral vaporization of the prostate (TURVP) and patients undergoing high performance laser prostatectomy(HPS). The surgical smoke produced from TURVP and HPS laser prostatectomy contains potentially harmful chemical compounds, although HPS laser prostatectomy produced less surgical smoke than TURVP. Urosol produced fewer types and a smaller amount of gas than normal saline during HPS laser prostatectomy	IIB	Quasi-experimental	Surgical urology patients	TURVP followed by HPS laser prostatectomy	TURVP followed by HPS laser prostatectomy with Urosol irrigation to TURVP followed by HPS laser prostatectomy with normal saline irrigation	36	Toxic compounds generated by TURVP and HPS laser prostatectomy

118	Rey JM, Schramm D, Hahnloser D, Marinov D, Sigrist MW. Spectroscopic investigation of volatile compounds produced during thermal and radiofrequency bipolar cautery on porcine liver. Meas Sci Technol. 2008;19(7):075602.	Both cautery methods generate comparable water and CO2 molar fractions but significantly different ammonia, methanol, and ethanol molar fractions. Differences in the latter molar fractions are due to the different temperature and chemical properties of the cautery. Carbon dioxide and methanol are produced at greater concentrations by thermal bipolar cautery. Radiofrequency bipolar cautery results in greater concentrations of ethanol during tissue vaporization of porcine liver.	IIB	Quasi-experimental	Porcine liver tissue	Smoke generation by cauterization	Thermal vs radiofrequency bipolar cautery	2	Composition and concentration of chemicals (methanol, ethanol, ammonia, water and carbon dioxide)produced by lasers using photoacoustic spectrometry as a measure
119	Hollmann R, Hort CE, Kammer E, Naegele M, Sigrist MW, Meuli-Simmen C. Smoke in the operating theater: an unregarded source of danger. Plast Reconstr Surg. 2004;114(2):458-463.	Surgical plume from electrocautery poses a potential health danger to the operating staff. The degree of the threat remains unclear. Because of the mechanical barrier, the tubus and the high dilution, respectively, both the patient and the anesthesiologist are scarcely or not at all endangered. Selective measurements of the plume verify alarming components. Follow-up studies must be given high priority and include particulate material and biological impurities in addition to the gasiform components. Therefore, the definition of standardized sample drawing and a more comprehensive specification of occupational exposure limits are necessary.	IIB	Quasi-experimental study	Smoke samples during a reduction mammoplasty	Dissection and resection of breast tissue	Analysis of the plume	25 samples	Identification and quantification of 11 different gases

120	Gianella M, Hahnloser D, Rey JM, Sigrist MW. Quantitative chemical analysis of surgical smoke generated during laparoscopic surgery with a vessel-sealing device. Surg Innov. 2014;21(2):170-179.	Harmless concentrations of methane (<34 ppm), ethane (<2 ppm), and ethylene (<10 ppm) were detected. Traces of carbon monoxide (<3.2 ppm) and of the anesthetic sevoflurane (<450 ppm) were also found. Adverse health effects for operating room personnel due to some of those substances (eg, toluene, styrene, xylene) can be excluded.	IIB	Quasi experimental	Laparoscopic colon resection surgery	Vessel sealing device	NA	31 smoke samples of 6 laparoscopic colon resections	Chemical composition of surgical smoke
121	Gianella M, Sigrist MW. Infrared spectroscopy on smoke produced by cauterization of animal tissue. Sensors. 2010;10(4):2694-2708.	No correlation between smoke composition and the atmosphere or the kind of cauterized tissue was found.	IIB	Quasi experimental	NA	Smoke production with electro knife cauterization in CO2 atmosphere	Concentrations of ethane, ethene, and water vapor in different types of animal tissues	15 smoke samples	Composition of surgical smoke
122	Lindsey C, Hutchinson M, Mellor G. The nature and hazards of diathermy plumes: a review. AORN J. 2015;101(4):428-442.	Conflicting evidence relative to the hazards associated with plume are documented in the literature. Factors such as instrument, tissue, length of surgery, and tissue type may affect the toxins and particulate released in the plume. Inconclusive evidence exist, but protective wear and practices to minimize exposure should be taken to minimize risks to healthcare personnel.	IIIB	Systematic review	NA	Smoke evacuation	NA	NA	Nature and hazards of surgical smoke plume
123	Okoshi K, Kobayashi K, Kinoshita K, Tomizawa Y, Hasegawa S, Sakai Y. Health risks associated with exposure to surgical smoke for surgeons and operation room personnel. Surg Today. 2015;45(8):957-965.	The authors reviewed the hazards of surgical smoke and the means of protecting OR personnel, and conclude that to reduce the hazards surgical smoke should be removed by an evacuation system. Surgeons should encourage the evacuation of smoke to minimize the potential health hazards to the entire perioperative team.	VB	Literature review	NA	NA	NA	NA	Surgical plume hazards and risk-reduction strategies

124	Bergbrant IM, Samuelsson L, Olofsson S, Jonassen F, Ricksten A. Polymerase chain reaction for monitoring human papillomavirus contamination of medical personnel during treatment of genital warts with CO2 laser and electrocoagulation. Acta Derm Venereol. 1994;74(5):393-395.	There is a risk of contamination of the operator by HPV DNA during both CO2 laser and electrocoagulation treatment. The authors recommend the use of face masks, smoke evacuation and decontamination of PPE after each session. Additional studies are needed to evaluate the degree of HPV contamination of surgical equipment and the risk of contamination between patients.	IIIB	Non-experimental-descriptive	OR personnel performing procedures on HPV+ patient lesions	Diathermic and CO2 laser treatment of HPV DNA	Samples from the nostrils, nasolabial folds, and conjunctiva of the operating physician before and after the procedures.	30	HPV DNA
125	Abramson AL, DiLorenzo TP, Steinberg BM. Is papillomavirus detectable in the plume of laser-treated laryngeal papilloma? Arch Otolaryngol Head Neck Surg. 1990;116(5):604-607.	HPV cannot be detected in the smoke plume from vaporization of laryngeal human tissue containing HPV unless the suction device makes direct contact with the tissue during surgery. The risk of contracting HPV from smoke plume during surgery, is minimal. During endolaryngeal surgery for laryngeal papillomas, PPE (ie, mask, gloves, eye protection) must be worn for the entire procedure. The aspirate may contain intact viruses and should be treated as potentially infectious waste.	IIB	Quasi-experimental, cohort study	Patients with laryngeal HPV-containing warts	CO2 laser vaporization	Distance variations of suction tip and contact with laryngeal tissue	7 patients (5 children and 2 adults)	Presence of HPV
126	Hughes PS, Hughes AP. Absence of human papillomavirus DNA in the plume of erbium:YAG laser-treated warts. J Am Acad Dermatol. 1998;38(3):426-428.	The plume produced by erbium: YAG laser-treated warts does not contain HPV DNA and is a safe laser to use for HPV-wart ablation.	IIB	Quasi-experimental	Patients with histopathologically confirmed verrucae vulgares	Erbium-YAG laser beam treatment	Presence or absence of HPV in tissue samples of verrucae vulgaris, from five different patients	5	Presence of HPV DNA in the laser plume of erbium:YAG laser-treated human warts

127	Kunachak S, Sithisarn P, Kulapaditharom B. Are laryngeal papilloma virus-infected cells viable in the plume derived from a continuous mode carbon dioxide laser, and are they infectious? A preliminary report on one laser mode. J Laryngol Otol. 1996;110(11):1031-1033.	Papilloma virus-infected cells cannot survive the continuous mode of carbon dioxide laser irradiation. To avoid airborne transmission of surgical smoke containing laryngeal papilloma viral-infected cells and infectious viral particles, the CO2 laser parameters should be in a continuous mode with a power density equal to or greater than 1667 w/cm2	IIB	Quasi-experimental	Fresh specimens of papilloma tissue along with normal hypopharyngeal mucosa from known cases of recurrent laryngeal papilloma	CO2 laser beam, continuous mode with trapping of the generated laser plume	Cultures of each set of specimens composed of normal mucosa, fresh papilloma and plume-derived every day for 45 days	10 sets	Viability and infectivity of laryngeal papilloma virus-infected cells
128	Guideline: Work Health and Safety—Controlling Exposure to Surgical Plume (Document Number GL2015_002). January 19, 2015. New South Wales Ministry of Health. http://www0.health.nsw.gov.au/policies/gl/2015/pdf/GL2015_002.pdf. Accessed September 21, 2016.	Provides assistance in the management of risk associated with exposure to surgical plume.	Regulatory	Regulatory	NA	NA	NA	NA	NA
129	Guideline for a Safe Environment of Care, Part 2. In: Guidelines for Perioperative Practice. Denver, CO: AORN, Inc; 2016:263-288.	AORN provides specific guidelines focused on the design of the building structure, movement of patients, personnel, supplies, and equipment through the suite; safety during construction; environmental controls; maintenance of structural surfaces; power failure; response planning; security, and control of noise and distractions.	IVA	Clinical Practice Guideline	NA	NA	NA	NA	NA
130	Z305.13-13: Plume Scavenging in Surgical, Diagnostic, Therapeutic, and Aesthetic Settings. Toronto, ON: Canadian Standards Association; 2013.	Guidance on plume hazard control measures.	Regulatory	Regulatory	NA	NA	NA	NA	NA
131	Safety and Health Management Systems eTool. Occupational Safety and Health Administration. https://www.osha.gov/SLTC/etools/safetyhealth/comp3.html. Accessed September 21, 2016.	eTool on health hazard reduction, safety, and health management control od surgical smoke	VA	Expert Opinion	NA	NA	NA	NA	NA
132	American National Standards Institute. Laser Institute of America. American National Standard for Safe Use of Lasers in Health Care. Orlando, FL: Laser Institute of America; 2011.	A guide to aid the manufacturer, consumer, and general public with definitions, standards, practices, and control measures. Local exhaust ventilation should be used to evacuate laser generated airborne contaminants as close as possible to the point of smoke generation.	IVB	Clinical practice guideline	NA	NA	NA	NA	NA

133	American Association of Physics in Medicine, American College of Medical Physics. Medical Lasers: Quality Control, Safety Standards, and Regulations. Joint Report Task Group No 6. Madison, WI: Medical Physics Publishing; 2001.	The report addresses the need for a laser safety program, the background of various types of lasers and emission characteristics, development of a laser safety committee, operational aspects of a clinical laser safety committee, quality control and laser safety principles, and laser safety procedures for clinical use. Smoke evacuator units should be used since smoke plume is carcinogenic and mutagenic and possibly contaminated with bacteria and viruses.	IVB	Clinical practice guideline	NA	NA	NA	NA	NA
134	Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Settings, 2005. Centers for Disease Control and Prevention. http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5417a1.htm. Accessed September 21, 2016.	Given the changes in epidemiology and a request by the Advisory Council for the Elimination of Tuberculosis (ACET) for review and update of the 1994 TB infection-control document, CDC reassessed the TB infection-control guidelines for health-care settings. The report updates TB control recommendations reflecting shifts in the epidemiology of TB, advances in scientific understanding, and changes in health-care practice that have occurred in the United States during the preceding decade. The document places emphasis on actions to maintain momentum and expertise needed to avert another TB resurgence and to eliminate the lingering threat to HCWs, which is mainly from patients or others with unsuspected and undiagnosed infectious TB disease.	IVA	Clinical Practice Guideline	NA	NA	NA	NA	NA

135	Respirator Trusted-Source Information. The National Personal Protective Technology Laboratory. http://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/respsource.html. Accessed September 21, 2016.	Guidance for implementing and understanding the types of respirators, how to identify approved models, a listing of all NIOSH-approved and FDA-cleared surgical N95 respirators, and relevant User Notices	IVB	Clinical Practice Guideline	NA	NA	NA	NA	NA
136	Rengasamy S, Miller A, Eimer BC, Shaffer RE. Filtration performance of FDA-cleared surgical masks. J Int Soc Respir Prot. 2009;26:54-70.	Filtration performance of surgical masks vary widely for room air particles at constant flow and correlate with the penetration levels measured under cyclic flow conditions. Not all FDA-cleared surgical masks will provide similar levels of protection to wearers against infectious aerosols in the size range of many viruses. The protection provided by a surgical mask is dependent on face seal leakage of particles and the penetration through the filter media.	IIB	Quasi-experimental	Surgical masks	Room air particle penetration at constant flow, function of particle size, cyclic flow conditions, aerosol penetration measurement,	Various surgical masks from different manufacturers	5	Filtration performance for a wide size range of submicron particles-particle sizes and number of particles
137	Gao S, Koehler RH, Yermakov M, Grinshpun SA. Performance of facepiece respirators and surgical masks against surgical smoke: simulated workplace protection factor study. Ann Occup Hyg. 2016;60(5):608-618.	Surgical masks do not provide measurable protection against surgical smoke. Surgical mask respirators offer considerably improved protection versus surgical masks, while the N100 FFRs showed significant improvement over the surgical mask respirators. The face seal prototype offered a higher level of protection than the standard N100 filtering facepiece respirator, due to a tighter seal.	IIIA	Non-experimental	Volunteers	NA	Surgical masks, N95 surgical mask respirator (SMRs) and N100 filtering facepiece respirator (FFRs),	10	Simulated workplace protection factor
138	Davidson C, Green CF, Panlilio AL, et al. Method for evaluating the relative efficiency of selected N95 respirators and surgical masks to prevent the inhalation of airborne vegetative cells by healthcare personnel. Indoor and Built Environment. 2011;20(2):265-277.	A Collison nebulizer could generate mono-disperse bacterial aerosol from a monoculture to effectively test respiratory protection equipment total inward leakage.	IIB	Quasi-experimental	NA	Bioaerosol surrogate exposure	Five surgical masks, three N95 respirators and three surgical N95 respirators	11	Total inward leakage which is a function of both filter media efficiency and face seal leakage

139	Derrick JL, Li PT, Tang SP, Gomersall CD. Protecting staff against airborne viral particles: in vivo efficiency of laser masks. J Hosp Infect. 2006;64(3):278-281.	FFP2 masks provide a superior level of protection against airborne particles when compared to surgical masks and laser masks. Taping of the surgical masks and laser masks does not offer a significant difference in the level of protection when compared to untaped masks. To prevent airborne infection, a fitted FFP2 respirator provides better protection than a laser mask.	IIA	Quasi-experimental	Volunteers	Laser	Surgical mask, laser mask, taped surgical mask, taped laser mask, and FFP 2	8 of each mask configu ration	Particle counts inside and outside the protective device during a series of activities: normal breathing, deep breathing, turning the head from side to side, flexing and extending the head, talking, and bending over.
140	Eninger RM, Honda T, Adhikari A, Heinonen-Tanski H, Reponen T, Grinshpun SA. Filter performance of N99 and N95 facepiece respirators against viruses and ultrafine particles. Ann Occup Hyg. 2008;52(5):385-396.	The filtration performance of the N95 respirator approached that of the two models of N99 over the range of particle sizes tested (0.02 to 0.5mm). Filter penetration of the tested biological aerosols did not exceed that of inert NaCl aerosol. The results suggest that inert NaCl aerosols may generally be appropriate for modeling of filter penetration for similarly sized virions.	IIB	Quasi-experimental	NA	Virus aerosol delivery and ultrafine particle delivery	Performance of two models of N99 masks and one model of N95; three different flow rates per mask	NA	Filtration
141	Redmayne AC, Wake D, Brown RC, Crook B. Measurement of the degree of protection afforded by respiratory protective equipment against microbiological aerosols. Ann Occup Hyg. 1997;41(Suppl 1):636-640.	Biological aerosols act in a similar way to non-biological aerosols for corresponding aerodynamic diameter. The performance of high efficiency respirator filters can be compromised by poor fit of respiratory protective equipment to the face.	IIB	Quasi-experimental	Filters for full and half face respirators, disposable dust masks, and disposal surgical masks	Aerosol penetration	Various types of masks	15	Filtration performance.

142	Chen CC, Willeke K. Aerosol penetration through surgical masks. Am J Infect Control. 1992;20(4):177-184.	The mask that has the highest collection efficiency is not necessarily the best mask from the perspective of the filter-quality factor, which considers not only the capture efficiency but also the air resistance. Although surgical mask media may be adequate to remove bacteria exhaled or inhaled by health care workers, they may not be sufficient to remove the submicrometer-sized aerosols containing pathogens to which health care workers are potentially exposed.	IIB	Quasi-experimental	Surgical masks and respirators	Exposure of masks to a test aerosol in a filter test chamber using a size-fractioning aerosol generator.	Flow rate variation (5-100 L/minute) of surgical masks and industrial-type respirators	6	Aerosol penetration characteristics
143	Weber A, Willeke K, Marchioni R, et al. Aerosol penetration and leakage characteristics of masks used in the health care industry. Am J Infect Control. 1993;21(4):167-173.	The protection provided by surgical masks may be insufficient in environments containing potentially hazardous submicrometer-sized aerosols.	IIB	Quasi-experimental study	Surgical masks	Aerosolization	Surgical masks with different filter media and shapes versus more protective dust-mist-fume respirator	8	Aerosol particle penetration of the filter media and induced face-seal leakage
144	Nezhat C, Winer WK, Nezhat F, Nezhat C, Forrest D, Reeves WG. Smoke from laser surgery: is there a health hazard? Lasers in Surgery & Medicine. 1987;7(4):376-382.	The smoke consisted of particles with a mean aerodynamic diameter of 0.31 microns. This size range has two consequences-10 it can be stated with 99.99% certainty that no cell-size particles including cancer cells are present in the smoke; and 2) particles of this size range are too small to be effectively filtered by surgical masks.	IIIB	Non-experimental	Patients undergoing laser laparoscopic surgical treatment for endometriosis and/or adhesions	NA	Level of exposure of the surgeon , scrub nurse, and all OR team members	32	Composition of surgical smoke produced during carbon dioxide laser endoscopic treatment

145	Kunachak S, Sobhon P. The potential alveolar hazard of carbon dioxide laser-induced smoke. J Med Assoc Thai. 1998;81(4):278-282.	Smoke particles derived from CO2 laser vaporization are within the occupational health hazard zone. Conventional surgical masks may not provide adequate protection from alveolar damage caused by contents in surgical smoke.	IIB	Quasi-experimental	Specimens from patients having laryngeal papilloma	Vaporization of the tissue with the CO2 laser beam, 10 W continuous mode and trapping of the generated laser smoke with 0.45 micron pore size micro filter, the second part was the same laser settings but trapping with a micro filter and cotton cloth surgical mask, and the third part was the same laser settings but trapping with a micro filter and paper surgical mask. The protocol represents direct smoke trapping, trapping after the smoke passes through a cotton mask, and trapping smoke after passing through a paper mask.	Effectiveness of 2 types of surgical masks	10	Size of smoke particles and the average particle density
146	Gatti JE, Bryant CJ, Noone RB, Murphy JB. The mutagenicity of electrocautery smoke. Plast Reconstr Surg. 1992;89(5):781-784.	Smoke produced during mammoplasty was found to contain mutagenic cells. It is unknown whether the smoke represents a serious health risk to OR personnel. Exposure should be minimized.	IIB	Quasi experimental	Mammoplasty procedures	Electrocautery	NA	2	Mutagenicity of cells in surgical smoke
147	Barrett WL, Garber SM. Surgical smoke: a review of the literature. Is this just a lot of hot air? Surg Endosc. 2003;17(6):979-987.	Surgical smoke is a hazard and should not be ignored. Surgical smoke is a toxin similar to cigarette smoke and tissue infected with viruses can be aerosolized by lasers. Surgeons should support efforts to minimize surgical smoke exposure to patients, OR personnel, and themselves.	VA	Literature review	NA	NA	NA	NA	Hazard of surgical smoke

148	Oberg T, Brosseau LM. Surgical mask filter and fit performance. Am J Infect Control. 2008;36(4):276-282.	None of these surgical masks exhibited adequate filter performance and facial fit characteristics to be considered respiratory protection devices. It is recommended to use NIOSH-certified respirators not surgical masks to reduce employee exposure to airborne infectious organisms.	IIB	Quasi-experimental	Volunteers	Qualitative and quantitative fit tests	Nine surgical masks (eg, surgical , laser, cup, flat, duckbill, ties, ear loops)	20	Subjective facial fit and filter performance of masks using
149	Chen SK, Vesley D, Brosseau LM, Vincent JH. Evaluation of single-use masks and respirators for protection of health care workers against mycobacterial aerosols. Am J Infect Control. 1994;22(2):65-74.	Surgical masks consisting of filter material performed better than did a surgical mask consisting only of a shell with a coarse pore structure. T	IIB	Quasi-experimental	Surgical masks and respirators	Aerosol generation	Various types of respirators	5	Filter efficiency of surgical masks and respirators
150	Hassan I, Drelichman ER, Wolff BG, Ruiz C, Sobczak SC, Larson DW. Exposure to electrocautery toxins: understanding a potential occupational hazard. Prof Saf. 2006;51(4):38-41.	No significant exposure to any of the measured chemical toxins was detected to either patients or surgeons in either surgical approach. Based on the study, the current strategies of smoke evacuation and air exchanges used in the OR are effective in minimizing exposure.	IIB	Quasi-experimental study	Colorectal surgical patients	Colorectal surgery	Open surgery versus laparoscopic surgery	10	Surgeon's exposure to benzene, toluene, xylene, acetone and styrene was measured. Patient's preoperative and postoperative blood was tested for benzene, ethyl benzene, toluene, xylene, carboxyhemoglobin and cyanide.
151	Wenig BL, Stenson KM, Wenig BW, Tracey D. Effects of plume produced by the Nd:YAG laser and electrocautery on the respiratory system. Lasers Surg Med. 1993;13(2):242-245.	Smoke plume byproduct causes pathologic changes in rat lungs and smoke evacuation may minimize the adverse effects caused by surgical smoke inhalation.	IIB	Quasi-experimental study	Sprague-Dawley rats	Phase 1-plume exposure for 2 minutes followed by 2 minutes of rest for four treatments for 4 days for 3 rats. Phase 2-plume exposure for 4 minutes followed by 2 minutes of rest for 4 sessions for 7 days for 3 rats. Phase 3-same as Phase e2 except duration was 14 days. One rat was a control for each phase.	Behavioral changes and histologic analysis of the rats from the 3 phases and the control animals.	12	Histologic lung changes

152	Baggish MS, Elbakry M. The effects of laser smoke on the lungs of rats. Am J Obstet Gynecol. 1987;156(5):1260-1265.	The severity of pulmonary pathology increased proportionately with the duration of the exposure where the most severe changes were seen. The fine particulate matter in the smoke played a role in congestive interstitial pneumonia. The authors concluded that exposure to smoke produced by lasers resulted in congestive interstitial pneumonia, bronchiolitis. and emphysema in the test subjects. Smoke evacuation should be used to protect the OR team.	IIA	Quasi-experimental study	Rats	Carbon dioxide laser vaporization	The lungs of the animals after total laser plume exposure of either 32 minutes, 112 minutes, 224 minutes, and 0 minutes (control).	13	Lung tissue damage and observed behavioral changes
153	Baggish MS, Baltoyannis P, Sze E. Protection of the rat lung from the harmful effects of laser smoke. Lasers Surg Med. 1988;8(3):248-253.	The study demonstrated that inhalation of laser smoke and particulate matter is harmful to mammalian lungs. By-products of laser plume are harmful to breathe and proper protection must be used by all personnel exposed to laser smoke.	IIB	Quasi-experimental study	Sprague-Dawley white rats	Exposure to surgical smoke generated by a laser	Filtered versus unfiltered smoke exposure and no smoke exposure	14	Pathological changes in the microscopic slides of the lungs
154	Hill DS, O'Neill JK, Powell RJ, Oliver DW. Surgical smoke—a health hazard in the operating theatre: a study to quantify exposure and a survey of the use of smoke extractor systems in UK plastic surgery units. J Plast Reconstr Aesthet Surg. 2012;65(7):911-916.	The long-term effects of chronic surgical smoke exposure remains unproven. Surgical smoke is mutagenic and contains the same carcinogens as tobacco smoke. The dangers of passive exposure to tobacco smoke are well documented. Smoke evacuators are recommended. Additional research is needed.	IIB	Quasi-experimental	Plastic surgery patients	Electrocautery ablation	Cutting vs coagulation	Six human muscle tissue samples and 78 porcine tissue samples	Diathermy device use in minutes

155	Wollmer W. Problems caused by laser plume, especially considering laser microlaryngoscopy. Adv Otorhinolaryngol. 1995;49:20-22.	Reporting of a systematic investigation in a EUREKA joint project by four German institutions sponsored by the German Minister of Research and Technology. Preliminary results include the contents of laser plume, the size of aerosol particles, the higher amount of carbon monoxide as more carbonization occurs, and the order of magnitude of volatile organic compounds.	VB	Literature review/organizational experience	NA	NA	NA	NA	Gas chromatographic-mass spectrometric analysis of small particles and volatile organic compounds.
156	Hou M-F, Lin G-T, Tang C-S, et al. Reducing dust using the electrocautery pencil with suction combined with the infusion catheter in mastectomy. Am Surg. 2002;68(9):808-811.	The concentration of dust produced by the conventional method of smoke evacuation, using a metal suction tube held by an assistant was significantly greater than the concentration of dust using an electrocautery suctioning method. The cost of using electrocautery is lower than using a metal suction tube held by an assistant with a separate electrocautery pencil (vs. combined).	IB	Randomized controlled trial	Modified radical mastectomy patients	Air sampling of surgical smoke	IV catheter suction-electrocautery pencil combination vs electrocautery pencil with metal suction tube held by an assistant	80	Total dust concentration
157	Hubner M, Sigrist MW, Demartines N, Gianella M,bClavien PA, Hahnloser D. Gas emission during laparoscopic colorectal surgery using a bipolar vessel sealing device: a pilot study on four patients. Patient Saf Surg. 2008;2:22.	The use of a vessel sealing device does not produce known toxic substances at levels high enough to cause concern to users or patients.	IIB	Quasi-experimental study	Laparoscopic colon surgery patients	Ligasure bipolar sealing device	The detected spectra in the surgical smoke were compared to the available spectra of known toxins.	4	surgical smoke content

158	Janda P, Leunig A, Sroka R, Betz CS, Rasp G. Preliminary report of endolaryngeal and endotracheal laser surgery of juvenile-onset recurrent respiratory papillomatosis by Nd:YAG laser and a new fiber guidance instrument. Otolaryngol Head Neck Surg. 2004;131(1):44-49.	Fiber guidance instrument enables a precise and easy treatment of respiratory papillomatosis with fiber-guided laser systems (eg, Nd:YAG-, di-ode-, and KTP-lasers) and an effective removal of infectious laser plume and toxic pyrolysis products. Continuous suctioning ensured an optimum view of the surgical site and minimal exposure to the potential infectious laser smoke and toxic pyrolysis products for the patient and the surgeon.	IIB	Quasi experimental	Children (4-8 years of age) with juvenile-onset recurrent respiratory papillomatosis	Nd: YAG laser vaporization with fiber guidance system	Rate of recurrence	5	Ease of use; visibility of surgical fields; presence of plume
159	Khajuria A, Maruthappu M, Nagendran M, Shalhoub J. What about the surgeon? Int J Surg. 2013;11(1):18-21.	A review of blood-borne pathogens, radiation exposure, biomechanical stresses and fatigue, and the adverse effects of diathermy fumes to the operating surgeon, followed by risk-minimization strategies.	VB	Literature review	NA	NA	NA	NA	Surgical plume hazards
160	OSH Answers Fact Sheets: Laser Plumes—Health Care Facilities. Canadian Center for Occupational Health and Safety. https://www.ccohs.ca/oshanswers/phys_agents/laser_plume.html. Accessed September 21, 2016.	Fast facts that provide guidance on laser plume content, potential health hazards, and minimizing exposure to laser plume.	VB	Expert opinion	NA	NA	NA	NA	NA
161	Mattes D, Silajdzic E, Mayer M, et al. Surgical smoke management for minimally invasive (micro) endoscopy: an experimental study. Surg Endosc. 2010;24(10):2492-2501.	Smoke evacuation from endoscopic cavities, as small as 2 cm in diameter through minimally invasive ports as small as 20 gauge, may be safe and efficient if sufficient gas exchange is provided during smoke generation by a laser or electrosurgical instruments. Maintaining low and constant pressure in the cavity during gas exchange and using a special construction design for the suction is necessary to provide an unobstructed view and to minimize the potential toxic side effects of surgical smoke.	IIB	Quasi-experimental study	Bovine scleral tissue	KTP laser vaporization and smoke evacuation	Intracavital pressure and gas flow without and with smoke evacuation	4	Amount of surgical smoke

162	Pillinger SH, Delbridge L, Lewis DR. Randomized clinical trial of suction versus standard clearance of the diathermy plume. Br J Surg. 2003;90(9):1068-1071.	Smoke evacuation of the diathermy plume resulted in a significant reduction in the amount of smoke reaching the level of the operator's mask. Although the risk of diathermy smoke inhalation is currently unknown, use of an evacuation system appears is recommended.	IB	Randomized controlled clinical trial	Patients undergoing thyroid or parathyroid dissection procedures	Smoke evacuation	Control-standard diathermy equipment; Study group- diathermy smoke evacuation system	30	Amount of smoke reaching the level of the operator's mask measured with an aerosol monitor
163	Makama GJ, Ameh EA. Hazards of surgical diathermy. Niger J Med. 2007;16(4):295-300.	Continuous exposure to electrocautery devices in surgical practice is associated with potential risks to OR personnel and risk-reduction strategies should be implemented.	VB	Literature review	NA	NA	NA	NA	Hazard of surgical smoke
164	Nori S, Greene MA, Schrager HM, Falanga V. Infectious occupational exposures in dermatology—a review of risks and prevention measures: I. For all dermatologists. J Am Acad Dermatol. 2005;53(6):1010-1019.	A review of occupational infectious risks from percutaneous exposures, aerosolized infectious particles and cryotherapy, followed by guidelines for management and post-exposure prophylaxis of common occupational exposures, and means to minimize risk of exposure.	VA	Literature review	NA	NA	NA	NA	NA
165	Freitag L, Chapman GA, Sielczak M, Ahmed A, Russin D. Laser smoke effect on the bronchial system. Lasers Surg Med. 1987;7(3):283-288.	Smoke inhalation resulted in severe inflammation and production of inflammatory cells. The side effects of smoke inhalation during laser surgery should not be overlooked and appropriate methods to minimize exposure should be implemented.	IIB	Quasi-experimental	Sheep	Laser-vaporization	Single and repetitive exposures to smoke	11 sheep	Bronchial damage

166	Guidelines for Environmental Infection Control in Health-Care Facilities. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention; 2003. http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_hcf_03.pdf. Accessed September 21, 2016.	To minimize the potential cross-contamination via a number of airborne and other transmissible microorganisms, adherence to CDC Guidelines for Environmental Infection Control and institutional-specific guidelines for environmental infection control are paramount to minimizing the occurrence of infections among health care workers.	IVA	Clinical Practice Guideline	NA	NA	NA	NA	NA
167	Charles K. Effects of laser plume evacuation on laser in situ keratomileusis outcomes. J Refract Surg. 2002;18(3 Suppl):S340-S342.	Evacuation of the laser plume with tubing and vacuum improved refractive and uncorrected visual acuity outcomes	IIIB	Non-experimental-retrospective analysis	Patients undergoing LASIK	Evacuation of laser plume	LASIK procedures with and without laser plume evacuation	199	Lasik outcomes of intended correction and visual acuity
168	Born H, Ivey C. How should we safely handle surgical smoke? Laryngoscope. 2014;124(10):2213-2215.	Review of best practices to reduce exposure to surgical smoke.	VB	Literature review	OR personnel	NA	NA	NA	Hazard of surgical smoke and risk reduction strategies.
169	Sanderson C. Surgical smoke. J Perioper Pract. 2012;22(4):122-128.	Evidence is lacking to conclusively demonstrate the harmful effect of surgical smoke on human health; however, evidence is lacking to conclusively state that surgical smoke does not affect health. Literature was reviewed for evidence-based guidelines to change practice if necessary and improve the OR environment.	VB	Literature review	NA	NA	NA	NA	Evidence on smoke content produced by medical lasers
170	O'Grady KF, Easty AC. Electrosurgery smoke: hazards and protection. J Clin Eng. 1996;21(2):149-155.	Animal and human studies suggest that inhalation of the small particles contained in surgical plume is dangerous. Only with education regarding the hazards of electrosurgical smoke and current techniques can the potential hazards associated with surgical smoke be reduced.	VB	Literature review	NA	NA	NA	NA	Surgical plume hazards
171	Fader DJ, Ratner D. Principles of CO2/erbium laser safety. Dermatol Surg. 2000;26(3):235-239.	Summary of known hazards of CO2 laser and erbium laser	VB	Literature review	NA	NA	NA	NA	Hazards of surgical lasers

172	Bargman H. Laser-generated airborne contaminants. J Clin Aesthet Dermatol. 2011;4(2):56-57.	The generation, contents, risks and means of protection through evacuation and respiratory protection are outlined in the commentary. The laser safety officer and laser operator should use proper scavenging systems properly.	VC	Expert Opinion	NA	NA	NA	NA	Risk reduction relative to surgical smoke
173	Gates MA, Feskanich D, Speizer FE, Hankinson SE. Operating room nursing and lung cancer risk in a cohort of female registered nurses. Scand J Work Environ Health. 2007;33(2):140-147.	Long-term exposure to surgical smoke, as measured by the duration of operating room employment, does not appear to increase the risk of lung cancer	IIIA	N0n-experimental,longitudinal descriptive	OR nurses	NA	OR nurses versus non0OR nurses	86747	Lung cancer
174	Voorhies RM, Lavyne MH, Strait TA, Shapiro WR. Does the CO2 laser spread viable brain-tumor cells outside the surgical field? J Neurosurg. 1984;60(4):819-820.	CO2 debris does not contain viable tumor cells and does not pose a risk to the surgical personnel, or to the patient by spreading viable tumor cells into the air or contaminating the surgical fields.	IIB	Quasi-experimental study	Adult male rats injected with C6 glioma cells	CO2 laser vaporization	Petri dishes with laser debris vs Petri dishes without laser debris (control)	6	Viable tumor cells
175	Oosterhuis JW, Verschueren RC, Eibergen R, Oldhoff J. The viability of cells in the waste products of CO2-laser evaporation of Cloudman mouse melanomas. Cancer. 1982;49(1):61-67.	It is unlikely that viable tumor cells are in the waste products produced by vaporization of tumors.	IIB	Quasi-experimental	Mouse tissue	CO2 laser beam	in vivo and in vitro viable cell production	127	Presence of viable melanoma cells in surgical smoke
176	Stocker B, Meier T, Fliedner TM, Plappert U. Laser pyrolysis products: sampling procedures, cytotoxic and genotoxic effects. Mutat Res. 1998;412(2):145-154.	The laser pyrolysis products originating from animal tissues must be classified as cytotoxic, genotoxic, and mutagenic. The OR team is exposed chronically to these substances and there may be a cumulative effect posing a potential health hazard. Additional studies are needed.	IIA	Quasi-experimental	Animal tissue	Irradiation with a CO2 laser	Different types of porcine tissue (ie, fat, skin, muscle, liver)	20	Analysis of the genotoxic and mutagenic effects of laser pyrolysis

177	Plappert UG, Stocker B, Helbig R, Fliedner TM, Seidel HJ. Laser pyrolysis products-genotoxic, clastogenic and mutagenic effects of the particulate aerosol fractions. Mutat Res. 1999;441(1): 29-41.	Pyrolysis products are strong inducers of cytotoxic effects. The ability and extent to induce genotoxic and mutagenic effects are dependent on the type of tissue irradiated. Particulate fraction of laser pyrolysis aerosols from tissue have to be classified as cytotoxic, genotoxic, clastogenic, and mutagenic. The amount of damage to the tissue particulate is dose dependent and may pose a risk to the health of OR staff and patients if inhaled.	IIA	Quasi-experimental	Porcine tissue	CO2 laser irradiation	Fat, skin, muscle, and liver tissue	4	cytotoxic, genotoxic, clastogenic, mutagenic effects
178	Hensman C, Baty D, Willis RG, Cuschieri A. Chemical composition of smoke produced by high-frequency electrosurgery in a closed gaseous environment: an in vitro study. Surg Endosc. 1998;12(8):1017-1019.	Electrosurgical smoke produced in a closed environment contains several toxic chemicals. The effects of these on cell viability, macrophage, and endothelial cell activation are not known but are being investigated. Measures to reduce smoke and evacuate it during endoscopic surgery are advisable.	IIB	Quasi-experimental study	Fresh porcine liver	Smoke was produced in vitro by high-frequency electrocutting of fresh porcine liver in helium, CO2, and air-saturated closed environments. Smoke samples were collected and analyzed by gas chromatography–mass spectrometry (GCMS).	Chemical constituents of electrosurgical smoke produced in air, CO2, and helium	3	Highly toxic and carcinogenic chemicals in smoke produced by electrocutting of porcine liver in a closed environment
179	Hensman C, Newman EL, Shimi SM, Cuschieri A. Cytotoxicity of electro-surgical smoke produced in an anoxic environment. Am J Surg. 1998;175(3):240-241.	Electrosurgical smoke is cytotoxic. Sublethal effects at lower dilutions are currently being investigated.	IIB	Quasi-experimental study	Pig liver	Cutting the liver with an electrosurgical hook knife and the collected smoke was equilibrated with cell culture medium. MCF-7 human breast carcinoma cells were exposed briefly to the cell culture medium	Helium environment versus CO2 environment	Not stated	Cytotoxic effects of surgical smoke produced in vitro in a closed environment similar to minimally invasive surgery
180	Gonzalez-Bayon L, Gonzalez-Moreno S, Ortega-Perez G. Safety considerations for operating room personnel during hyperthermic intraoperative intraperitoneal chemotherapy perfusion. Eur J Surg Oncol. 2006;32(6):619-624.	New procedures for hyperthermic, intraoperative intraperitoneal chemotherapy perfusion are safe techniques for patients and healthcare workers provided occupational exposure is avoided.	VA	Literature review	HCWs	NA	NA	NA	NA

181	Wisniewski PM, Warhol MJ, Rando RF, Sedlacek TV, Kemp JE, Fisher JC. Studies on the transmission of viral disease via the CO2 laser plume and ejecta. J Reprod Med. 1990;35(12):1117-1123.	Intact viral and bacterial organisms were absent under microscopic view; Southern Blot Analysis detected positive virus; however, the viability of the virus is unknown as the amount of DNA was insufficient for determination which may be in part due to the vaporization of the cells. The ejecta studies confirm that even though smoke evacuation was used, the OR suite is contaminated with particles ≤ 100-200 microns in diameter leaving the laser impact site at up to 5 m/second. Viral masks seem ineffective in protecting the wearer from inspired virus. Additional research is needed on viral viability after exposure to laser energy and improvements in technology to eliminate most of the smoke plume.	IIB	Quasi-experimental study	Patients with biopsy-confirmed vulvar condylomata or cervical intraepithelial neoplasia; heifers	CO2 laser vaporization	Plume and ejecta of laser tissue debris; light and electron microscopy of the debris from genital skin and mucosal surfaces; Southern Blot studies of ejecta from genital HPV lesions; and transmission of bovine papilloma virus *in vivo* via airborne laser debris in dairy cattle	10-humans;2-animals	Viral viability and transmission of viral disease via CO2 laser debris
182	Ilmarinen T, Auvinen E, Hiltunen-Back E, Ranki A, Aaltonen L-M, Pitkäranta A. Transmission of human papillomavirus DNA from patient to surgical masks, gloves and oral mucosa of medical personnel during treatment of laryngeal papillomas and genital warts. Eur Arch Otorhinolaryngol. 2012;269(11):2367-2371.	Wearing surgical laser plume masks with protective gloves and goggles seem to protect medical personnel from acquiring HPV infections during treatment. Careful disposal of the contaminated gloves, instruments and other protective equipment used is important to prevent HPV transmission.	IIB	Quasi-experimental study	10 male surgical patients (5 with laryngeal papillomas, 5 with genital warts)	CO2 laser treatment of recurrent respiratory papillomatosis and genital warts	Presence or absence of HPV on gloves, masks, and oral mucosa of the employees and oral mucosa of the patients	120	HPV transmission from the patient to the protective surgical masks, gloves, & oral mucosa of medical personnel during the treatment of laryngeal papillomas & genital warts

183	Kofoed K, Norrbom C, Forslund O, et al. Low prevalence of oral and nasal human papillomavirus in employees performing CO2-laser evaporation of genital warts or loop electrode excision procedure of cervical dysplasia. Acta Derm Venereol. 2015;95(2):173-176.	HPV prevalence was not higher in employees participating in electrosurgical treatment or cryotherapy of genital warts, or loop electrode excision procedure compared with those who did not. All the healthcare workers involved in CO2 laser treatment report using some protective measures such as gloves, smoke evacuation, and laser plume masks	IIIB	Non-experimental-descriptive study	Healthcare workers employed at departments of gynecology and derma-venereology	Oral and nasal samplings	Healthcare employees participating in the treatment of genital warts and those who did not	314	Mucosal HPV
184	Gloster HM Jr, Roenigk RK. Risk of acquiring human papillomavirus from the plume produced by the carbon dioxide laser in the treatment of warts. J Am Acad Dermatol. 1995;32(3):436-441.	When warts are grouped together, without specification to anatomic site, surgeons are no more likely to acquire warts than a person in the general population. HPV that cause genital warts may represent more of a hazard to the surgeon. HPV types that cause genital warts have a predilection for infecting the upper airway mucosa, and laser plume containing these viruses may represent more of a hazard to the surgeon.	IIIB	Non-experimental	CO2 laser surgeons & population-based control subjects	CO2 laser treatment of warts.	CO2 laser surgeons & population-based control subjects	570-surgeons; 5202 patients with warts/ 105,720 population of the county	HPV
185	Manson LT, Damrose EJ. Does exposure to laser plume place the surgeon at high risk for acquiring clinical human papillomavirus infection? Laryngoscope. 2013;123(6):1319-1320.	Review of the literature on cross-contamination with HPV from HPV-infected surgical plume is low. Evacuation of surgical smoke from the surgical field is likely an effective measure to prevent viral contamination.	VB	Literature review	NA	NA	NA	NA	Studies and case reports on cross-contamination of surgeons by inhalation of HPV-positive surgical plume
186	Taravella MJ, Weinberg A, Blackburn P, May M. Do intact viral particles survive excimer laser ablation? Arch Ophthalmol. 1997;115(8):1028-1030.	Attenuated varicella-zoster virus does not seem to survive excimer laser ablation. The authors recommend safety precautions (eg, mask) during the procedure. Additional research is needed to determine infectiousness of other viruses after exposure to the excimer laser.	IIB	Quasi-experimental study	Cells inoculated with varicella-zoster virus	Ablation with excimer laser	PCR analysis of 4 series of ablations and control	12	Survival of varicella-zoster virus after exposure to the excimer laser

187	Hagen KB, Kettering JD, Aprecio RM, Beltran F, Maloney RK. Lack of virus transmission by the excimer laser plume. Am J Ophthalmol. 1997;124(2):206-211.	Excimer laser ablation of the cornea of HIV and/or herpes infected patients does not pose a risk to the surgeon, as the plume does not contain live-enveloped virus that may transmit HIV and/or herpes virus.	IIB	Quasi-experimental, controlled-comparative study	NA	Excimer laser ablation	Viral-infected tissue vs non-infected control	20	Viral infections
188	Smoke Evacuation Systems, Surgical. Plymouth Meeting, PA: ECRI Institute; 2015.	Smoke evacuation systems are designed to capture the smoke generated during surgical procedures where there is thermal destruction of tissue. Product comparison of smoke evacuation systems used during surgical procedures. The devices are also called central smoke evacuation systems, laser smoke evacuators, local smoke evacuator systems, permanent smoke evacuation systems, portable smoke evacuation systems, and stand-alone smoke evacuators.	VA	Expert opinion	NA	NA	NA	NA	NA
189	Smith JP, Topmiller JL, Shulman S. Factors affecting emission collection by surgical smoke evacuators. Lasers Surg Med. 1990;10(3):224-233.	Distance of the evacuator from the surgical site, the direction and speed of the external air flow, and the flow rate of the smoke evacuator were identified as factors that affected the efficacy of the smoke evacuation device in removing smoke. The authors concluded that smoke evacuators are more efficient at the highest flow rate possible, with a capacity at least 40 CFM, and the smoke evacuators nozzle of the evacuator as close as possible to the surgical site.	IIB	Quasi-experimental study	Animal tissue	CO2 laser and Smoke evacuator	Performance of the smoke evacuator by distance of the nozzle from surgical site, direction and speed of external air flow, and evacuator flow rate.	18	Smoke evacuator performance in regards to efficiency of collection

190	Smith JP, Moss CE, Bryant CJ, Fleeger AK. Evaluation of a smoke evacuator used for laser surgery. Lasers Surg Med. 1989;9(3):276-281.	At distances greater than 2 inches, smoke escaped from the evacuation system. At two inches the smoke evacuation system completely collected the fumes from the site when the evacuator was operational. Distances greater than 2 inches is likely to result in in exposure to high concentrations for the OR team near the laser site and also result in in background concentrations increasing.	IIB	Quasi-experimental study	Animal tissue	CO2 laser beam	Various distances (ie, 2, 6, 12 inches) of the smoke evacuation tubing from the animal tissue	1	Smoke containment
191	ECRI. Surgical smoke evacuation systems. Healthcare Risk Control. 2000;4(Surgery and Anesthesia 17.1):1-7.	Smoke evacuation systems are high-flow vacuum sources designed to capture the smoke generated during the use of lasers and electrosurgical units.	VA	Expert opinion	NA	NA	NA	NA	NA
192	Watson DS. Surgical smoke evacuation during laparoscopic surgery. AORN J. 2010;92(3):347-350.	Healthcare facilities claim to be smoke free. Some of these same facilities allow surgeries to be performed on a routinely without the evacuation of surgical smoke placing perioperative team members and patients at risk for unnecessary exposure to chemicals, blood, and smoke by-products.	VB	Literature review	NA	NA	NA	NA	NA

193	Ott D. Smoke production and smoke reduction in endoscopic surgery: preliminary report. Endosc Surg Allied Technol. 1993;1(4):230-232.	The production of surgical smoke in the peritoneal cavity during laparoscopic surgery allows for absorption of toxic chemicals via the respiratory tract and peritoneum. Abnormal physiologic elevation of methaemoglobin occurs from the intra-abdominal absorption of smoke. The exchange of normal hemoglobin/ methaemoglobinemia establishes the toxicity and hazard of intra-abdominal laser and electrosurgical smoke. Smoke evacuation is needed to minimize exposure.	IIB	Quasi-experimental study	Female patients undergoing laparoscopic procedures	Control-no smoke generating device; Study group- laser or cautery used	Methaemoglobin levels before induction of anesthesia, at 5, 15, 30, 60, 90, & 180 minutes after the start of surgery	50	Methaemoglobin levels
194	Nezhat C, Seidman DS, Vreman HJ, Stevenson DK, Nezhat F, Nezhat C. The risk of carbon monoxide poisoning after prolonged laparoscopic surgery. Obstet Gynecol. 1996;88(5):771-774.	Carbon monoxide poisoning is not an end result of prolonged laparoscopic surgery. The reasons may be the aggressive smoke evacuation that minimizes exposure to carbon monoxide and the active elimination of carbon monoxide by ventilation with high oxygen concentrations.	IIB	Quasi-experimental	Women undergoing laparoscopic surgery in which smoke was generated	High-flow carbon dioxide insufflation, intensive intra-abdominal smoke evacuation, and controlled hyperventilation with 50-100% oxygen	Blood samples before and after surgery	27	Level of carboxyhemoglobin in the blood
195	Ulmer BC. Best practices for minimally invasive procedures. AORN J. 2010;91(5):558-575.	Surgical smoke may pose a risk for patients during laparoscopic surgery. Smoke can reduce visibility in the abdomen, delaying the procedure, and the patient may experience adverse side effects, such as unrecognized hypoxia and port site metastases	VB	Literature review	NA	NA	NA	NA	NA

196	Dobrogowski M, Wesolowski W, Kucharska M, Sapota A, Pomorski LS. Chemical composition of surgical smoke formed in the abdominal cavity during laparoscopic cholecystectomy—assessment of the risk to the patient. Int J Occup Med Environ Health. 2014;27(2):314-325.	Compounds that are produced in the abdominal cavity during laparoscopic surgery is caused by tissue pyrolysis in the presence of carbon dioxide atmosphere. All patients undergoing laparoscopic procedures are at risk of absorbing and excreting smoke by-products. Exposure of the patient to emerging chemical compounds is short in duration. Concentrations of benzene and toluene found in the urine were significantly higher after surgery than before.	IIIB	Non-experimental	Laparoscopic cholecystectomy patients	tissue pyrolysis	NA	82	Identification and chemical analysis via gas chromatography of surgical smoke
197	Bigony L. Risks associated with exposure to surgical smoke plume: a review of the literature. AORN J. 2007;86(6):1013-1020.	Nurses should advocate for healthcare worker safety in addition to patient safety. Nurses should insist on the use of smoke evacuators and educate others on the research.	VA	Literature review	NA	NA	NA	NA	NA
198	29 CFR §1910.1030: Bloodborne Pathogens. Occupational Safety and Health Administration. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10051. Accessed September 21, 2016.	Personal protective equipment and disposal practices to appropriately manage products potentially containing bloodborne pathogens.	Regulatory	Regulatory	NA	NA	NA	NA	NA
199	Standards of perioperative nursing practice. In: Guidelines for Perioperative Practice. Denver, CO: AORN, Inc; 2015:693-708.	The standards of perioperative nursing provide a mechanism to delineate the responsibilities of registered nurses practicing in the perioperative environment.	IVB	Clinical Practice Guideline	NA	NA	NA	NA	NA
200	Scott H, Mustard P, Cooper H, Hayde C. Development of a plume evacuation policy—a health and safety issue. Dissector. 2014;41(4):10-14.	A quality improvement project was developed to improve staff awareness of the hazards of surgical smoke, improve use of smoke evacuation equipment and PPE, and measure compliance with the plume evacuation policy.	VB	Organizational experience	OR personnel	Education, smoke evacuation and policy development	NA	NA	Compliance with smoke evacuation policy

201	Edelman DS, Unger SW. Bipolar versus monopolar cautery scissors for laparoscopic cholecystectomy: a randomized, prospective study. Surg Laparosc Endosc. 1995;5(6):459-462.	Cutting and charring ability using the monopolar and bipolar devices during gallbladder surgery were similar. Coagulation was superior in the monopolar group, but surgical smoke was less in the bipolar scissors group.	IB	Randomized controlled clinical trial	Laparoscopic Cholecystectomy Patients	Surgical scissors	Bipolar scissors versus monopolar scissors	80	Outcomes included: surgeon satisfaction, device superiority in cutting, charring, and coagulation ability and device production of surgical smoke.
202	Kim FJ, Sehrt D, Pompeo A, Molina WR. Laminar and turbulent surgical plume characteristics generated from curved- and straight-blade laparoscopic ultrasonic dissectors. Surg Endosc. 2014;28(5):1674-1677.	Turbulent flow is disruptive to laparoscopic visibility with greater field obstruction and requires longer settling than laminar plume. Ultrasonic dissectors with straight blades have more consistent oscillations and generate more laminar flow compared with curved blades. Surgeons may avoid laparoscopic smearing from maximum plume generation depending on the blade configuration.	IIB	Quasi-experimental	Bovine liver tissue samples	Activation of straight and curved blade laparoscopic ultrasonic dissectors	Plume settlement times with curved and straight ultrasonic dissector blades	3	Surgical plume emission (laminar or turbulent) and plume settlement time between curved and straight blades
203	Kim FJ, Sehrt D, Pompeo A, Molina WR. Comparison of surgical plume among laparoscopic ultrasonic dissectors using a real-time digital quantitative technology. Surg Endosc. 2012;26(12):3408-3412.	In the coagulation setting the SonoSurg generated the least amount of surgical plume , the Sonocision obstructed approximately 4%, and the ACE obstructed 25% of the laparoscopic field with plume generation. In the cutting setting SonoSurg and Sonocisoin generated the least obstruction and the ACE the most obstruction.	IIA	Quasi-experimental, controlled-comparative study	Bovine liver tissue samples	Activation of the devices for 2 seconds and 3 seconds at the industry-specified coagulation and cutting settings	The Covidien Cordless Sonicision, the Harmonic ACE, and the Olympus SonoSurg	3	The number of pixels containing plume used to find the percentage of plume in the field.
204	Sherman JA, Davies HT. Ultracision: the Harmonic scalpel and its possible uses in maxillofacial surgery. Br J Oral Maxillofac Surg. 2000;38(5):530-532.	The harmonic scalpel uses high-frequency mechanical energy and produces considerably less smoke or smell than either diathermy or laser, which reduces the need for instrument exchanges and smoke evacuation.	VC	Expert opinion	NA	NA	NA	NA	NA

205	Shabbir A, Dargan D. Advancement and benefit of energy sealing in minimally invasive surgery. Asian J Endosc Surg. 2014;7(2):95-101.	Review of the history of cautery, principles of electrosurgery, energy sealing devices, advanced bipolar, and smoke evacuation.	VA	Literature review	NA	NA	NA	NA	NA
206	Schneider A, Doundoulakis E, Can S, Fiolka A, Wilhelm D, Feuner H. Evaluation of mist production and tissue dissection efficiency using different types of ultrasound shears. Surg Endosc. 2009;23(12): 2822-2826.	Ultrasonic shears are effective devices for bloodless cutting, but the mist produced by the ultrasonic shears impedes the visual field during the surgical procedure. Mist may be reduced by decreasing power, which would result in a longer surgery time.	IIB	Quasi-experimental study	Animal tissue	Tissue dissection with ultrasonic devices	Ultrasonic devices named "A, B, C, D"	2	Quantitative measurement of mist production, dissection time, and number of cuttings
207	Devassy R, Gopalakrishnan S, De Wilde RL. Surgical efficacy among laparoscopic ultrasonic dissectors: are we advancing safely? A review of literature. J Obstet Gynecol India. 2015;65(5):293-300.	The radiofrequency device (RF) and ultrasonic dissector(USS) are both useful and widely used and are safer than monopolar devices. RF Device is slower than USS, as it cannot achieve coagulation and cutting at the same time. Ultrasonic causes less thermal damage than the RF device.	VA	Literature review	NA	NA	Ultrasonic device and energy -based device	NA	Plume production and lateral thermal damage
208	Bui MH, Breda A, Gui D, Said J, Schulam P. Less smoke and minimal tissue carbonization using a thulium laser for laparoscopic partial nephrectomy without hilar clamping in a porcine model. J Endourol. 2007;21(9):1107-1111.	Laparoscopic partial nephrectomy without hilar clamping using a thulium laser effectively cuts and coagulates tissue while preserving field visibility and producing minimal surgical smoke.	IIB	Quasi-experimental	Porcine Models	Thulium laser	NA	5	Histological effect of laser on kidney tissue and maximal depth of laser penetration into renal parenchyma

209	Kisch T, Liodaki E, Kraemer R, et al. Electrocautery devices with feedback mode and Teflon-coated blades create less surgical smoke for a quality improvement in the operating theater. Medicine (United States). 2015;94(27):e1104.	In feedback mode (FM), more surgical smoke was created using stainless steel blades compared with Teflon blades. Differences between FM and pure-cut mode were found for SSB and TB (P<0.001), but not for sharp-edged Teflon blades (SETB). The use of both Teflon blades and feedback mode is associated with reduced amounts of surgical smoke created during cutting. The perioperative team may benefit form adopting new technologies which could contribute to the prevention of smoke-related diseases.	IIB	Quasi-experimental	Porcine tissue with skin	Cutting of tissue	Sharp-edged Teflon-coated blades (SETBs), normal-shaped Teflon-blades (TBs) ,or stainless steel blades (SSBs).	7	Amount of surgical smoke created by electrocautery feedback mode and Teflon-coated blades
210	Wagner JA, Bodendorf MO, Grunewald S, Simon JC, Paasch U. Circular directed suction technique for ablative laser treatments. Dermatol Surg. 2013;39(8):1184-1189.	Combination of providing cool air flow during laser treatment and circular suction is an approach for directed cooling air streams and streamed plume evacuation that does not impede the view of the surgical field.	IIB	Quasi-experimental	Simulated smoke plume	Nebulizer a and suction	Conventional suction device versus circular suction technique	10	Skin surface temperature and smoke evacuation
211	Liang JH, Pan YL, Kang J, Qi J. Influence of irrigation on incision and coagulation of 2.0-μm continuouswave laser: an ex vivo study. Surg Laparosc, Endosc Percutan Tech. 2012;22(3):e122-e125.	Slow irrigation has an acceptable effect on the incision and coagulation ability of 2.0 micrometer continuous-wave laser. The mechanism of the effect was that irrigation changed energy distribution during laser-tissue interaction. Slow irrigation is efficient and acceptable method to evacuate surgical smoke during laparoscopic surgery.	IIB	Quasi-experimental study	Canine kidneys simulating human tissue undergoing laparoscopic surgery	Irrigation	Irrigation rates of 0,20, and 80ml/minute combined with laser power settings of 20 and 40 watts)	18	Depth of the slots and the thickness of the coagulation layer at different combinations of laser power and irrigation rate.
212	Liang J-H, Xu C-L, Wang L-H, Hou J-G, Gao X-F, Sun Y-H. Irrigation eliminates smoke formation in laser laparoscopic surgery: ex vivo results. Surg Laparosc, Endosc Percutan Tech. 2008;18(4):391-394.	Smoke generation rate was increased with laser power whereas decreased with irrigation rate. Irrigation eliminates laser generated smoke formation and it shows potential for future application in laser laparoscopic surgery.	IIB	Quasi-experimental	Canine kidneys simulating human tissue undergoing laparoscopic surgery	Irrigation	Irrigation rates of 0,20,40,60,80, and 100ml/minute combined with laser power settings of 20,30,40, and 50 watts)	24	Efficiency of irrigation in eliminating laser surgical smoke

213	Nicholson G, Knol J, Houben B, Cunningham C, Ashraf S, Hompes R. Optimal dissection for transanal total mesorectal excision using modified CO2 insufflation and smoke extraction. Colorectal Dis. 2015;17(11):O265-O267.	With proper technique, the operating surgeon is able to perform the surgical dissection in a stable operating environment with increased visibility compared to the standard approach	VB	Expert Opinion	Colorectal surgery patients	NA	NA	NA	Surgical field visibility
214	Vavricka SR, Tutuian R, Imhof A, et al. Air suctioning during colon biopsy forceps removal reduces bacterial air contamination in the endoscopy suite. Endoscopy. 2010;42(9):736-741.	During gastroenterology procedures, the bacterial load can be reduced during the removal of biopsy forceps with the application of air suction. This may reduce transmission of infectious agents during gastrointestinal endoscopy procedures.	IB	Randomized controlled trial	Elective colonoscopy patients	Suctioning of smoke	Removal of biopsy forceps without and with suctioning following contact with the sigmoid mucosa.	50	Effectiveness of air suctioning during removal of biopsy forceps in reducing bacterial air contamination measured as the bioaerosol burden
215	Schultz L. An analysis of surgical smoke plume components, capture, and evacuation. AORN J. 2014;99(2):289-298.	The ideal smoke evacuation system to protect surgical team members and patients is one that captures as much surgical smoke as possible and evacuates it to a remote site without recirculation of that air into the OR. Smoke evacuation systems must be tested and documented to be high quality and cost effective	VB	Literature review	NA	NA	NA	NA	Plume components, capture, and evacuation properties
216	Jordan C, Thomas MB, Evans ML, Green A. Public policy on competency: how will nursing address this complex issue? J Contin Educ Nurs. 2008;39(2):86-91.		VA	Literature review	NA	NA	NA	NA	NA

217	Nicola JH, Nicola EMD, Vieira R, Braile DM, Tanabe MM, Baldin DHZ. Speed of particles ejected from animal skin by CO2 laser pulses, measured by laser Doppler velocimetry. Phys Med Biol. 2002;47(5):847-856.	During tissue ablation, natural deceleration occurs. When the particles emitted reach minimum speed, if no collisions occur, they will only decelerate by gravitational action and the residual kinetic energy will send the particles up to approximately 0.87 m from the skin surface. The ejected particles may carry viable cells acting as disease vectors during laser surgery. The researchers results suggest that laser Doppler velocimetry techniques should be sued to measure the speed of particles ejected from healthy and pathological human tissue to help establish safe conditions during laser surgery.	IIA	Quasi-experimental	Animal tissue	CO2 laser pulsation	Distribution of speed frequency corresponding to the number of ejected particles from a single laser shot for three different laser powers	8 with 30 measurements from each subject	Particle speed ejected from tissue exposed to CO2 laser pulses
218	42 CFR §482. Conditions of participation for hospitals. Centers for Medicare & Medicaid Services. Department of Health and Human Services. https://www.gpo.gov/fdsys/granule/CFR-2011-title42-vol5/CFR-2011-title42-vol5-part482/content-detail.html. Accessed September 21, 2016.	Outline of hospital administration and basic functions for hospitals receiving federal support.	Regulatory	Regulatory	NA	NA	NA	NA	NA
219	42 CFR §416. Ambulatory surgical services. Centers for Medicare & Medicaid Services. Department of Health and Human Services. https://www.cms.gov/Regulationsand-Guidance/Legislation/CFCsAndCoPs/ASC.html. Accessed September 21, 2016.	Federal description, guidelines, and rules for payment, services, and scope for ambulatory surgical service centers.	Regulatory	Regulatory	NA	NA	NA	NA	NA
220	State Operations Manual Appendix A: Survey Protocol, Regulations and Interpretive Guidelines for Hospitals. Rev 151; 2015. Centers for Medicare & Medicaid Services. https://www.cms.gov/Regulations-and-Guidance/Guidance/Manuals/downloads/som107ap_a_hospitals.pdf. Accessed September 21, 2016.	CMS guidance on survey protocols and regulations for hospitals.	Regulatory	Regulatory	NA	NA	NA	NA	NA
221	State Operations Manual Appendix L: Guidance for Surveyors: Ambulatory Surgical Centers. Rev 137; 2015. Centers for Medicare & Medicaid Services. https://www.cms.gov/Regulations-and-Guidance/Guidance/Manuals/downloads/som107ap_l_ambulatory.pdf. Accessed September 21, 2016.	CMS guidance on survey protocols and regulations for ambulatory surgical centers.	Regulatory	Regulatory	NA	NA	NA	NA	NA

222	Oganesyan G, Eimpunth S, Kim SS, Jiang SI. Surgical smoke in dermatologic surgery. Dermatol Surg. 2014;40(12):1373-1377.	Most dermatologic surgeons do not use smoke management within their practices.	IIIB	Non-experimental	Dermatologic surgeons	NA	NA	316	Surgical smoke evacuation practices and the amount and chemical composition of surgical smoke
223	Ball K. Surgical smoke evacuation guidelines: compliance among perioperative nurses. AORN J. 2010;92(2):e1-e23.	Organizational structure, perception, and culture are associated with smoke evacuator compliance. The following predictors increase surgical smoke evacuation compliance- increased education and training, positive perceptions regarding smoke evacuation, understanding smoke evacuation recommendations, larger facility size, and strong leadership support.	IIIB	Non-experimental	AORN staff nurses	Survey	NA	777	Factors associated with smoke evacuation compliance