REFERENCE #	CITATION	EVIDENCE TYPE	SAMPLE SIZE/ POPULATION	INTERVENTION(S)	CONTROL/ COMPARISON	OUTCOME MEASURE(S)	CONCLUSION(S)	CONSENSUS SCORE
1	Ulmer BC. The hazards of surgical smoke. *AORN J.* 2008;87(4):721-734.	Literature Review	n/a	n/a	n/a	n/a	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
2	Vortman R, McPherson S, Cecilia Wendler M. State of the science: a concept analysis of surgical smoke. *AORN J* . 2021;113(1):41-51.	Literature Review	n/a	n/a	n/a	n/a	Principle-based concept analysis of surgical smoke with definition and implications for practice.	VA
3	Ott DE. Proposal for a standard for laser plume filter technology. *J Laser Appl* . 1994;6(2):108-110.	Literature Review	n/a	n/a	n/a	n/a	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.	VB
4	Mayo-Yánez M, Calvo-Henríquez C, Lechien JR, Fakhry N, Ayad T, Chiesa-Estomba CM. Is the ultrasonic scalpel recommended in head and neck surgery during the COVID-19 pandemic? State-of-the-art review. *Head Neck* . 2020;42(7):1657-1663.	Literature Review	n/a	n/a	n/a	n/a	During COVID-19, the use of the ultrasonic scalpel should be avoided, particularly in upper airway. If used, a smoke evacuator must be used.	VB
5	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.	Quasi-experimental	mixture of human blood and tissue cultures with HIV-1	powered surgical instruments (ie, router, bone saw, irrigator, electrocautery)	n/a	presence of HIV-1 from aerosols	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
6	Mihashi S, Jako GJ, Incze J, Strong MS, Vaughan CW. Laser surgery in otolaryngology: interaction of CO2 laser and soft tissue. *Ann N Y Acad Sci.* 1976;267(1):263-294.	Quasi-experimental	animal tongue tissue	CO2 laser irradiation	no CO2 laser irradiation	physiomechanical and physiochemical histological changes	Early study describing the smoke plume containing airborne tissue particles resulting from CO2 laser on tissue. Laser induces rapid vaporization of solid and water components of tissue.	IIC
7	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.	Quasi-experimental	animal tissue	CO2 laser	electrocautery	mutation assay of smoke condensates	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
8	Kwak HD, Kim SH, Seo YS, Song K-J. Detecting hepatitis B virus in surgical smoke emitted during laparoscopic surgery. *Occup Environ Med* . 2016;73(12):857-863.	Nonexperimental	11 patients positive for HBV who underwent laparoscopic surgery, Korea	n/a	n/a	presence of HBV in 'aerosolized gas' surgical smoke produced during laparoscopic procedures	Hepatitis B Virus (HBV) is detectable in surgical smoke. Steps should be taken to protect staff when surgical smoke is generated during surgery on patients with known HBV infection.	IIIC

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9	Fox-Lewis A, Allum C, Vokes D, Roberts S. Human papillomavirus and surgical smoke: a systematic review. *Occup Environ Med* . 2020;77(12):809-817.	Systematic Review	n/a	n/a	n/a	n/a	Systematic review of 21 research studies related to HPV and surgical smoke. HPV DNA is detectable in surgical smoke and can contaminate the upper airway. HPV DNA has been identified in surgical smoke and can contaminate the upper airway. Though transmission remains unknown, HPV surgical smoke should be considered infectious. LEV, room air exchanges, and full PPE including respiratory protection should be employed during surgery that produces surgical smoke in patients with HPV infection.	IIIB
10	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.	Quasi-experimental	HIV-infected cells	CO2 laser	Vapor of HIV infected cells vs uninfected HUT 78 cells	presence of HIV DNA	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
11	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.	Quasi-experimental	tumor cell lines	various surgical devices: electrocautery, radio-frequency ablation, ultrasonic scalpel	n/a	viable cancer cells in surgical smoke and carcinogenicity	Surgical smoke produced from ultrasonic scalpels used to vaporize or dissect cancerous tissue contains viable cancer cells.	IIA
12	Fletcher JN, Mew D, Descôteaux JG. Dissemination of melanoma cells within electrocautery plume. *Am J Surg.* 1999;178(1):57-59.	Quasi-experimental	3 samples of B15 melanoma cells	Electrocautery	Fulguration at 10, 20, 30 watts	presence of viable malignant cells in suspension within electrocautery plume	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
13	Nahhas WA. A potential hazard of the use of the surgical ultrasonic aspirator in tumor reductive surgery. *Gynecol Oncol* . 1991;40(1):81-83.	Case Report	n/a	n/a	n/a	n/a	The ultrasonic aspirator used in tumor reductive surgery creates vapor that may contain viable cells. Protective eyewear is recommended.	VB
14	Benson SM, Novak DA, Ogg MJ. Proper use of surgical N95 respirators and surgical masks in the OR. *AORN J.* 2013;97(4):457-470.	Literature Review	n/a	n/a	n/a	n/a	Healthcare workers should wear appropriate PPE as respiratory protection. PPE is a second line of defense in the presence of surgical smoke.	VA
15	Addley S, Quinn D. Surgical smoke—what are the risks? *Obstet Gynaecol* . 2019;21(2):102-106	Literature Review	n/a	n/a	n/a	n/a	Surgical smoke awareness as an occupational health hazard remains relevant as energy-based device use increases. Staff education , safe work practices, staff training, and risk mitigation should be included in hospital plans. The authors call for a formal review to develop practice guidelines.	VB
16	Schultz L. An analysis of surgical smoke plume components, capture, and evacuation. *AORN J.* 2014;99(2):289-298.	Literature Review	n/a	n/a	n/a	n/a	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

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17	Ragde SF, Jørgensen RB, Føreland 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.	Quasi-experimental	Five different types of surgical procedures (ie, hip replacement, nephrectomy, breast reduction, abdominoplasty, transurethral urologic resection), Norway	use of electrocautery	n/a	Ultrafine particle exposure	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.	IIB
18	Bratu AM, Petrus M, Patachia M, Dumitras DC. Carbon dioxide and water vapors detection from surgical smoke by laser photoacoustic spectroscopy. *UPB Sci Bull Series A.* 2013;75(2):139-146.	Quasi-experimental	10 animal tissue samples	CO2 laser	different powers and irradiation times	water vapor and carbon dioxide concentrations	Laser applied to fresh tissue contains a concentration of water vapor ranging from 1% to 11%.	IIB
19	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.	Quasi-experimental	31 patients undergoing laparoscopic colon resection surgery	vessel sealing device	n/a	chemical composition of surgical smoke	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
20	Laser/electrosurgery plume. Occupational Safety and Health Administration. https://www.osha.gov/laser-electrosurgery-plume. Accessed August 30, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	Employers should understand the hazards related to surgical smoke.	VA
21	Eshleman EJ, LeBlanc M, Rokoff LB, et al. Occupational exposures and determinants of ultrafine particle concentrations during laser hair removal procedures. *Environ Health.* 2017;16(1):30.	Quasi-experimental	17 laser hair removal procedures, United States	n/a	use of smoke evacuator, duration of procedure, body part of laser hair removal, laser type, use of lotion	Ultrafine particle concentrations	Laser hair removal produces ultrafine particles. Duration of procedure is a strong indicator of ultrafine particle concentrations. Smoke evacuators placed farther than the recommended 2 inches of the source of surgical smoke provides minimal protection. Smoke evacuation should be used for all laser hair removal procedures.	IIC
22	Cheng NY, Chuang HC, Shie RH, Liao WH, Hwang YH. Pilot studies of VOC exposure profiles during surgical operations. *Ann Work Expo Health.* 2019;63(2):173-183.	Nonexperimental	24 breath samples from operating room personnel participating in surgical procedures where electrosurgery was used	n/a	n/a	VOC measurements	18 VOCs were detected in breath samples of surgical staff team members. Further research should focus on the effect of chemical exposure over time.	IIIB

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23	Anderson M, Goldman RH. Occupational reproductive hazards for female surgeons in the operating room: a review. *JAMA Surg.* 2020;155(3):243-249.	Literature Review	n/a	n/a	n/a	n/a	Review of occupational hazards present in the operating room related to female surgeon factors for increased rates of infertility and reproductive outcomes. Surgical smoke cited as a potentially contributing factor for adverse pregnancy. Control of exposures to potential occupational hazards should be managed for pregnant surgeons and compliance to existing guidelines and standards should be continued, however these may not be enough to fully protect reproductive outcomes.	VA
24	Ball K. Surgical smoke evacuation guidelines: compliance among perioperative nurses. *AORN J.* 2010;92(2):e1-e23.	Nonexperimental	777 perioperative nurses	n/a	n/a	factors associated with smoke evacuation compliance	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
25	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(1):54.	Case Report	n/a	n/a	n/a	n/a	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
26	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.	Case Report	n/a	n/a	n/a	n/a	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
27	Hallmo P, Naess O. Laryngeal papillomatosis with human papillomavirus DNA contracted by a laser surgeon. *Eur Arch Otorhinolaryngol.* 1991;248(7):425-427.	Case Report	n/a	n/a	n/a	n/a	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
28	Choi C, Do IG, Song T. Ultrasonic versus monopolar energy-based surgical devices in terms of surgical smoke and lateral thermal damage (ULMOST): a randomized controlled trial. *Surg Endosc* . 2018;32(11):4415-4421.	RCT	40 women with gynecologic disease (such as uterine myoma, adenomyosis, and ovarian tumors undergoing TLH, Republic of Korea	ultrasonic energy group (n = 20)	monopolar energy (n = 20)	visibility measured by researchers with videotaped footage using a Likert scale. Lateral thermal damage measured by blinded pathologist.	Ultrasonic energy-based surgical device (ESD) created significantly less visible surgical smoke or vapor and caused less lateral thermal damage during colpotomy compared to monopolar device.	IB

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29	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.	Quasi-experimental	5 fresh porcine psoas muscle tissue samples	Four instrument types (ie, harmonic scalpel, bipolar macroforceps, monopolar shears, and floating ball)	background	visibility	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 particles 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
30	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.	Quasi-experimental	20 processed animal tissue samples, Germany	laser ablation	different treatment wavelengths (980nm, 1350nm, 1470nm)	vision quality affected by surgical smoke	Smoke generation depends on the size of the wavelength used when ablating tissue.	IIA
31	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.	Nonexperimental	3 laparoscopic cholecystectomy video and images	n/a	n/a	Detection of surgical smoke using one class support vector machine (OCSVM)	The OCSVM system effectively captures the irregular movement of surgical smoke.	IIIB
32	Ansell J, Warren N, Wall P, et al. Electrostatic precipitation is a novel way of maintaining visual field clarity during laparoscopic surgery: a prospective double-blind randomized controlled pilot study. *Surg Endosc.* 2014;28(7):2057-2065.	RCT	30 patients undergoing laparoscopic cholecystectomy	electrostatic precipitation	no electrostatic precipitation	visibility and delays	Electrostatic precipitation improves visibility during laparoscopic surgery and reduces case delays due to smoke clearing.	IB
33	Nduka CC, Monson JR, Menzies-Gow N, Darzi A. Abdominal wall metastases following laparoscopy. *Br J Surg.* 1994;81(5):648-652.	Expert Opinion	n/a	n/a	n/a	n/a	Diathermy smoke may theoretically contribute to the etiology of abdominal wall metastasis following laparoscopic surgery.	VC
34	Ott DE. Carboxyhemoglobinemia due to peritoneal smoke absorption from laser tissue combustion at laparoscopy. *J Clin Laser Med Surg.* 1998;16(6):309-315.	Quasi-experimental	50 patients undergoing laparoscopic procedures	CO2 laser	no laser	carboxyhemoglobin levels and pulse oximetry	Carbon monoxide is created in large quantities during laparoscopy with lasers and is absorbed through the peritoneal cavity. Symptoms of smoke poisoning are seen with the elevation. Removal of smoke is recommended.	IIB
35	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.	Quasi-experimental	7 porcine models undergoing laparoscopic resection of liver	monopolar cautery	n/a	intraabdominal carbon monoxide, hydrogen cyanide, acrylonitrile, and benzene levels; methemoglobin and carboxyhemoglobin	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

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36	Esper E, Russell TE, Coy B, Duke BE 3rd, Max MH, Coil JA. Transperitoneal absorption of thermocautery-induced carbon monoxide formation during laparoscopic cholecystectomy. *Surg Laparosc Endosc.* 1994;4(5):333-335.	Quasi-experimental	15 patients undergoing laparoscopic cholecystectomy	thermocautery	n/a	intraperitoneal carbon monoxide levels; carboxyhemoglobin levels	Thermocautery produces carbon monoxide which builds in the peritoneum; however, brief intervals of exposure may explain why patient carboxyhemoglobin levels remain unchanged.	IIB
37	Control of smoke from laser/electric surgical procedures (DHHS [NIOSH] Publication No 96-128). The National Institute for Occupational Safety and Health. 1996. Accessed August 30, 2021.	Consensus	n/a	n/a	n/a	n/a	The hazards of surgical smoke can be controlled with local exhaust ventilation and work practice controls.	IVB
38	IFPN guideline for surgical plume (IFPN statement 1012). International Federation of Perioperative Nurses. https://www.ifpn.world/resources/education-tools. Accessed August 30, 2021.	Guideline	n/a	n/a	n/a	n/a	Surgical smoke (plume) should be evacuated as first line defense. Face masks/respiratory protection is second line of defense.	IVB
39	Standard: surgical plume. In: Murphy C, ed. Standards for Perioperative Nursing in Australia: Clinical Standards. Vol 1. 16th ed. Adelaide, South Australia: Australian College of Operating Room Nurses; 2020.	Guideline	n/a	n/a	n/a	n/a	ACORN states that patients and surgical staff members should be protected from the hazards of surgical plume (smoke). Recommendations include direction on the management of surgical plume.	IVB
40	AST Standards of Practice for Use of Electrosurgery 2012	Guideline	n/a	n/a	n/a	n/a	AST supports evacuation of surgical smoke from electrosurgery.	IVB
41	AST guidelines for best practices in laser safety. 2019. Association of Surgical Technologists. https://www.ast.org/uploadedFiles/Main_Site/Content/About_Us/Standard%20Laser%20Safety.pdf. Accessed August 30, 2021.	Guideline	n/a	n/a	n/a	n/a	AST supports evacuation of laser generated airborne contaminants.	IVB
42	Steege AL, Boiano JM, Sweeney MH. Secondhand smoke in the operating room? Precautionary practices lacking for surgical smoke. *Am J Ind Med.* 2016;59(11):1020-1031.	Nonexperimental	4533 healthcare workers including nurses, surgical technologists, anesthesia professionals, technicians, assistants	n/a	n/a	reports of exposure to surgical smoke and use of LEV/PPE/other	Organizations should create policies to stipulate LEV whenever surgical smoke is produced. The decision should not be up to individual operators because the hazard affects all team members in the procedure room.	IIIA
43	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.	Nonexperimental	12,228 nurses, anesthesia providers, OR personnel, physicians	n/a	n/a	training and employer standard procedures	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

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44	Asdornwised U, Pipatkulchai D, Damnin S, Chiswangwatanakul V, Boonsripitayanon M, Tonklai S. Recommended practices for the management of surgical smoke and bio-aerosols for perioperative nurses in Thailand. *J Perioper Nurs.* 2018;31(1):33-41.	Nonexperimental	377 OR nurses, Thailand	n/a	n/a	Reports of awareness, education & compliance of surgical smoke best practices. Reports of health effects of surgical smoke exposure.	In this sample of OR nurses in Thailand, headache was reported most frequently followed by sore throat, coughing/sneezing, weakness, and eye irritation. Also reported were nausea/dizziness, chronic bronchitis and asthma. Perioperative nurses should follow best practice guidelines to reduce exposure to surgical smoke.	IIIA
45	Ilce A, Yuzden GE, Yavuz van Giersbergen M. The examination of problems experienced by nurses and doctors associated with exposure to surgical smoke and the necessary precautions. *J Clin Nurs.* 2017;26(11-12):1555-1561.	Nonexperimental	81 doctors (n = 36) and nurses (n = 45), Turkey	n/a	n/a	surgical smoke safety measures	Surgeons and nurses report headache, watering of the eyes, cough, throat burning cough, smell absorbed in hair, nausea, drowsiness, dizziness, and sneezing from exposure to surgical smoke. Nurses experience significantly more coughs than surgeons. Protective measures such as surgical smoke evacuation and filtration should be used along with PPE. Education and training should be provided.	IIIB
46	Michaelis M, Hofmann FM, Nienhaus A, Eickmann U. Surgical smoke-hazard perceptions and protective measures in German operating rooms. *Int J Environ Res Public Health.* 2020;17(2):515.	Nonexperimental	surgeons (n = 359) and OR nurses (n = 142)	n/a	n/a	awareness of surgical smoke hazards and adherence to protective measures	Surgeons and assistant staff members may require more comprehensive education on the hazards of surgical smoke. Operating room nurses can advocate and lead implementation of surgical smoke safety measures.	IIIB
47	Wizner K, Nasarwanji M, Fisher E, Steege AL, Boiano JM. Exploring respiratory protection practices for prominent hazards in healthcare settings. *J Occup Environ Hyg.* 2018;15(8):588-597.	Nonexperimental	10,383 healthcare workers who routinely come into contact with identified respiratory hazards, United States	n/a	n/a	hazard-specific respiratory protection behaviors	Surgical masks are being worn when respiratory protection is recommended. Innovative training is necessary regarding hazard recognition, the application of engineering controls, and appropriate use of respirators vs surgical masks.	IIIB
48	Oganesyan G, Eimpunth S, Kim SS, Jiang SI. Surgical smoke in dermatologic surgery. *Dermatol Surg.* 2014;40(12):1373-1377.	Nonexperimental	316 dermatologic surgeons	n/a	n/a	surgical smoke evacuation practices	Most dermatologic surgeons do not use smoke management within their practices.	IIIB
49	Spearman J, Tsavellas G, Nichols P. Current attitudes and practices towards diathermy smoke. *Ann R Coll Surg Engl.* 2007;89(2):162-165.	Nonexperimental	118 general surgical consultants, specialist registrars, senior theatre nurses	n/a	n/a	smoke evacuator use and opinions of surgical smoke hazards	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

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50	Edwards BE, Reiman RE. Comparison of current and past surgical smoke control practices. *AORN J.* 2012;95(3):337-350.	Nonexperimental	1,356 perioperative nurses	n/a	n/a	surgical smoke control practices compared to previous study	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
51	Edwards BE, Reiman RE. Results of a survey on current surgical smoke control practices. *AORN J* . 2008;87(4):739-749.	Nonexperimental	623 perioperative nurses	n/a	n/a	compliance with best practices for smoke evacuation	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
52	Gavin DJ, Wilkie BD, Tay J, Loveday BPT, Furlong T, Thomson BNJ. Assessing the risk of viral infection from gases and plumes during intra-abdominal surgery: a systematic scoping review. *ANZ J Surg.* 2020;90(10):1857-1862.	Literature Review	n/a	n/a	n/a	n/a	No evidence to support the presence of respiratory viruses in peritoneal fluid.	VB
53	Bogani G, Ditto A, De Cecco L, et al. Transmission of SARS-CoV-2 in surgical smoke during laparoscopy: a prospective, proof-of-concept study. *J Minim Invasive Gynecol.* 2021;28(8):1519-1525.	Nonexperimental	17 patients undergoing laparoscopic GYN procedures in Italy during COVID-19 pandemic	n/a	n/a	SARS-CoV-2 presence in surgical smoke	SARS-CoV-2 might be theoretically transmitted through surgical smoke and aerosolized from fluid in the abdominal cavity.	IIIB
54	Moletta L, Pierobon ES, Capovilla G, et al. International guidelines and recommendations for surgery during COVID-19 pandemic: a systematic review. *Int J Surg.* 2020;79:180-188.	Literature Review	n/a	n/a	n/a	n/a	During the COVID-19 pandemic, recommended PPR and OR equipment should be available to minimize possible risk of transmission of the SARS-CoV-2 virus during surgery.	VA
55	Francis N, Dort J, Cho E, et al. SAGES and EAES recommendations for minimally invasive surgery during COVID-19 pandemic. *Surg Endosc.* 2020;34(6):2327-2331.	Consensus	n/a	n/a	n/a	n/a	SAGES and EAES recommend precautions during minimally invasive procedures to prevent potential transmission of coronavirus.	IVA
56	Porter J, Blau E, Gharagozloo F, et al. Society of Robotic Surgery review: recommendations regarding the risk of COVID-19 transmission during minimally invasive surgery. *BJU Int.* 2020;126(2):225-234.	Consensus	n/a	n/a	n/a	n/a	There is a lack of evidence about the presence of the coronavirus in electrocautery surgical smoke and in the CO2 used during minimally invasive surgery. Minimally invasive surgeons should reduce release of surgical smoke and CO2 into the operating room to reduce possible exposure to personnel.	IVA
57	Alqadi GO, Saxena AK. Smoke and particulate filters in endoscopic surgery reviewed during COVID-19 pandemic. *J Ped Endo Surg.* 2020;2(2):61-67.	Literature Review	n/a	n/a	n/a	n/a	Six laparoscopic smoke filters studies identified that hazardous chemicals can be removed utilizing ULPA, charcoal, or combination filter. No studies have demonstrated removal of viruses with smoke filters including the SARS-CoV-2 virus	VA

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58	Mintz Y, Arezzo A, Boni L, et al. The risk of COVID-19 transmission by laparoscopic smoke may be lower than for laparotomy: a narrative review. *Surg Endosc.* 2020;34(8):3298-3305.	Literature Review	n/a	n/a	n/a	n/a	Laparoscopy can be performed safely during COVID19 if precautions are taken. Precautions include management of pneumoperitoneum, evacuation of surgical smoke, minimization of surgical energy use.	VA
59	Pavan N, Crestani A, Abrate A, et al. Risk of virus contamination through surgical smoke during minimally invasive surgery: a systematic review of the literature on a neglected issue revived in the COVID-19 pandemic era. *Eur Urol Focus* . 2020;6(5):1058-1069.	Literature Review	n/a	n/a	n/a	n/a	Available evidence related to viruses and surgical smoke does not exclude a theoretical risk of the SARS-CoV-2 virus diffusion through surgical smoke. Although specific studies on SARS-CoV-2 virus in surgical smoke are needed, protective measures should be taken.	VA
60	Pini Prato A, Conforti A, Almstrom M, et al. Management of COVID-19-positive pediatric patients undergoing minimally invasive surgical procedures: systematic review and recommendations of the Board of European Society of Pediatric Endoscopic Surgeons. *Front Pediatr.* 2020;8:259.	Literature Review	n/a	n/a	n/a	n/a	During minimally invasive surgery in COVID-19 positive pediatric patients, surgeons should consider conservative options, utilize dedicated COVID-19 laparoscopic equipment, manage insufflation and desufflation to avoid leaks, and use lower power for electrocautery.	VA
61	Vourtzoumis P, Alkhamesi N, Elnahas A, Hawel JE, Schlachta C. Operating during COVID-19: is there a risk of viral transmission from surgical smoke during surgery? *Can J Surg.* 2020;63(3):E299-E301.	Literature Review	n/a	n/a	n/a	n/a	Surgical teams should practice smoke evacuation and respiratory protection despite a lack of evidence of SARS-CoV-2 presence in surgical smoke. The pandemic highlights the importance of expanding research and knowledge about surgical smoke towards enhancing personnel and patient safety.	VA
62	Zakka K, Erridge S, Chidambaram S, et al; PanSurg Collaborative Group. Electrocautery, diathermy, and surgical energy devices: are surgical teams at risk during the COVID-19 pandemic? *Ann Surg.* 2020;272(3):e257-e262.	Literature Review	n/a	n/a	n/a	n/a	COVID-19 transmission is unknown, however it is biologically plausible. Surgical teams should evacuate surgical smoke, wear appropriate PPE, and follow professional guidance.	VB
63	[COVID-19] Considerations for smoke evacuation during non-deferrable surgery [ECRI exclusive hazard report]. Health Devices Alerts. ECRI. https://www.ecri.org/Components/Alerts/Pages/TrackingUser/AlertDisplay.aspx?AId=1643206&entryID=2&Page=AlertDisplay. Published May 18, 2020. Accessed August 30, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	Expert opinion smoke evacuation clinical guidance for surgical staff in response to COVID-19 pandemic. Recommendations include minimizing generation of surgical smoke, use of engineering controls (passive and active devices) for all procedures that produce surgical smoke, and the use of ULPA filtering devices for both open and laparoscopic procedures.	VA
64	Mowbray NG, Ansell J, Horwood J, et al. Safe management of surgical smoke in the age of COVID-19. *Br J Surg* . 2020;107(11):1406-1413.	Expert Opinion	n/a	n/a	n/a	n/a	COVID-19 transmission remains unclear, however a theoretical risk of viral transmission . Minimally invasive surgeons should minimize risk through the use of evidence-based protective measures.	VA

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65	Van den Eynde J, De Groote S, Van Lerberghe R, Van den Eynde R, Oosterlinck W. Cardiothoracic robotic assisted surgery in times of COVID-19. *J Robot Surg.* 2020;14(5):795-797.	Expert Opinion	n/a	n/a	n/a	n/a	Robotic assisted cardiothoracic surgery during the COVID-19 pandemic can be performed as it has several advantages, though caution should be applied when using electrosurgical and ultrasonic devices, as well as during insufflation to prevent aerosolization of viral particles. One lung ventilation should be avoided and lowest possible insufflation pressures should be utilized.	VB
66	Guideline for transmission-based precautions. In: Guidelines for Perioperative Practice. Denver, CO: AORN, Inc; 2021:1097-1126.	Guideline	n/a	n/a	n/a	n/a	Provides guidance for transmission-based precautions in the perioperative area.	IVA
67	Interim infection prevention and control recommendations for healthcare personnel during the coronavirus disease 2019 (COVID-19) pandemic. Centers for Disease Control and Prevention. https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html. Updated February 23, 2021. Accessed August 30, 2021	Guideline	n/a	n/a	n/a	n/a	Provides guidance for infection prevention and control for healthcare personnel during the COVID-19 pandemic.	IVA
68	OSHA General Duty Clause. Occupational Safety and Health Administration. https://www.osha.gov/laws-regs/oshact/section5-duties. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Outline of general occupational safety and health duties of employers.	n/a
69	Occupational Safety and Health Act of 1970. Occupational Safety and Health Administration. https://www.osha.gov/laws-regs/oshact/completeoshact. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Regulation to ensure safe and healthful working conditions.	n/a
70	Galassi T. OSHA requirements for smoke plume generated from laser and electrosurgical instruments in dental offices and hospital operating rooms [Standards interpretations]. October 7, 2016. Accessed August 30, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	No specific OSHA standard addresses surgical smoke. Other applicable OSHA requirements include the General Duty Clause, Personal Protective Equipment, Respiratory Protection, and Air Contaminants.	VB
71	29 CFR 1910.132. General requirements. Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=22f04ddbddca6fe30d5f2073f85ab334&ty=HTML&h=L&mc=true&n=pt29.5.1910&r=PART#se29.5.1910_1132. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	General PPE requirements	n/a

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72	29 CFR 1910.134. Respiratory protection. Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=22f04ddbddca6fe30d5f2073f85ab334&ty=HTML&h=L&mc=true&n=pt29.5.1910&r=PART#se29.5.1910_1134. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Employers must adhere to respiratory protection regulations.	n/a
73	29 CFR 1910.1000 Air contaminants. Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=22f04ddbddca6fe30d5f2073f85ab334&ty=HTML&h=L&mc=true&r=SECTION&n=se29.6.1910_11000. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Regulation on exposure to air contaminants.	n/a
74	State plans. Occupational Safety and Health Administration. https://www.osha.gov/stateplans. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	State-based OSHA regulations.	n/a
75	Benson SM, Maskrey JR, Nembhard MD, Unice KM, Shirley MA, Panko JM. Evaluation of personal exposure to surgical smoke generated from electrocautery instruments: a pilot study. *Ann Work Expo Health.* 2019;63(9):990-1003.	Quasi-experimental	6 full-shift measurements of personal air quality; 2 background air samples, United States	smoke evacuator use during various surgeries using electrocautery	no smoke evacuator use during various surgeries using electrocautery	UFP and chemical concentrations	Further research should study UFP concentrations for individuals' breathing zones under different conditions and potential biological viability in particulate matter of surgical smoke. Engineering controls, LEV, and surgical N95s should be used to reduce possible exposure to ultrafine particles.	IIB
76	Sisler JD, Shaffer J, Soo JC, et al. In vitro toxicological evaluation of surgical smoke from human tissue. *J Occup Med Toxicol.* 2018;13(1):12.	Nonexperimental	electrocautery surgical smoke generated from human breast tissue samples, lab study	n/a	n/a	cytotoxicity, lactate dehydrogenase levels, and superoxide production	Surgical smoke may be cytotoxic and therefore could be considered an occupational hazard.	IIIB
77	Tan W, Zhu H, Zhang N, et al. Characterization of the PM2.5 concentration in surgical smoke in different tissues during hemihepatectomy and protective measures. *Environ Toxicol Pharmacol.* 2019;72:103248.	Quasi-experimental	50 patients undergoing hemihepatectomy, China	ultrasonic energy	electrocautery	PM2.5 concentrations	Liver tissue produces high concentrations of PM2.5 where ultrasonic scalpel produced higher concentrations as compared to electrosurgery. Researchers recommend double masking during liver procedures as particulate respirators (though better) are difficult to wear for long periods of time.	IIA

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78	Karjalainen M, Kontunen A, Saari S, et al. The characterization of surgical smoke from various tissues and its implications for occupational safety. *PLoS One* . 2018;13(4):e0195274.	Nonexperimental	10 porcine tissue samples, Finland	n/a	n/a	mass concentration and size distribution of surgical smoke particulate matter	The highest particulate matter concentration is found in liver tissue with medium levels found in renal cortex, renal pelvis, and skeletal muscle tissue. The lowest particulate matter concentrations are in skin, gray matter, white matter, bronchus, and subcutaneous fat. Liver tissue particulate matter concentrations remain in the 'very high' air quality index range, even with a smoke evacuator (assuming an 88% effectiveness). The researchers recommend smoke evacuation and particulate filtrations masks should be used for high-PM and medium-PM tissue surgery. Further studies are needed to validate these findings.	IIIB
79	Li CI, Pai JY, Chen CH. Characterization of smoke generated during the use of surgical knife in laparotomy surgeries. *J Air Waste Manag Assoc.* 2020;70(3):324-332.	Nonexperimental	30 obstetric and gynecologic procedures using electronic knife, Taiwan	n/a	n/a	contents of surgical smoke	Surgical smoke contains both suspended particulates and PAHs. Surgical smoke evacuators should be used.	IIIB
80	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.	Quasi-experimental	25 patients undergoing colorectal or peritonectomy procedures	high voltage electrosurgery	standard care	ultrafine particle levels in personal and stationary air samples	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
81	Taravella MJ, Viega J, Luiszer F, et al. Respirable particles in the excimer laser plume. *J Cataract Refract Surg.* 2001;27(4):604-607.	Quasi-experimental	2 eye-bank corneas	excimer laser ablation	background	presence of respirable-sized particles in the excimer laser plume	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
82	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.	Literature Review	n/a	n/a	n/a	n/a	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

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83	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.	Quasi-experimental	25 patients undergoing superficial, open abdominal, laparoscopic surgeries, open pelvic surgeries, and transurethral surgeries, China	Bipolar cautery for open and laparoscopic surgeries and resectoscope for transurethral surgery	varying distances from incision or site of generation of surgical smoke; wall suction vs no wall suction	fine particulate matter concentrations	The concentration of fine particles can reach unhealthy levels, especially for those closest to the location of surgical smoke generation. Wall suction may not be effective for smoke evacuation as it decreases fine particle inhalation dose by only 48%. Operating room personnel should be aware of potential hazards and take measures to prevent exposure to fine particulate matter in surgical smoke.	IIB
84	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.	Quasi-experimental	8 tissue samples from patients who underwent hysteroscopy for benign conditions	monopolar electrosurgical device	bipolar electrosurgical device	insoluble particulate matter	In vitro electrosurgical vaporization of tissue using a monopolar device produces particles smaller in diameter when compared to the particles produced using a bipolar device.	IIA
85	Brüske-Hohlfeld I, Preissler G, Jauch KW, et al. Surgical smoke and ultrafine particles. *J Occup Med Toxicol.* 2008;3:31.	Quasi-experimental	6 patients undergoing surgical procedures	electrocautery and argon plasma tissue coagulation	n/a	particle concentration	There is short term very high exposure to ultrafine particles for surgeons and close assisting personnel, alternating with longer periods of low exposure.	IIB
86	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.	Quasi-experimental	8 patients undergoing laparoscopic surgery and animal tissue samples	electrocautery	in vivo and in vitro conditions	morphology, size, and elemental composition of smoke particles	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
87	Van Gestel EAF, Linssen ES, Creta M, et al. Assessment of the absorbed dose after exposure to surgical smoke in an operating room. *Toxicol Lett* . 2020;328:45-51.	Nonexperimental	15 staff member air and urine samples, and room air samples from a general surgery operating room in Belgium	n/a	n/a	levels of PAHs and VOCs	Electrosurgical smoke contains low concentrations of VOCs and PAHs. Elevated O-creosol levels were detected, however it remains unclear if toluene exposure in surgical smoke is connected to O-creosol metabolites. Circulating nurses and scrub assistants may have increased exposure than surgeons.	IIIB
88	Kocher GJ, Sesia SB, Lopez-Hilfiker F, Schmid RA. Surgical smoke: still an underestimated health hazard in the operating theatre. *Eur J Cardiothorac Surg.* 2019;55(4):626-631.	Quasi-experimental	liver and muscle porcine tissue, Switzerland	electrocautery	no smoke evacuator compared to smoke evacuator (60% and 100%); 2 surgical masks also tested	VOC concentrations in surgical smoke	Surgical smoke evacuators may not provide protection against some harmful chemicals found in surgical smoke. Surgical masks provide no protection against inhaling VOCs from surgical smoke.	IIB

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89	Markowska M, Krajewski A, Maciejewska D, Jeleń H, Kaczmarek M, Stachowska E. Qualitative analysis of surgical smoke produced during burn operations. *Burns.* 2020;46(6):1356-1364.	Quasi-experimental	10 patients undergoing procedures for full-thickness burns	monopolar and bipolar electrocautery	escharotomy (n = 6); necrotomy (n = 4)	concentrations of volatile, nonpolar, organic compounds	Necrotic tissue and eschar tissue exposed to electrocautery produces surgical smoke containing complex toxic hydrocarbon derivatives. 153 volatile organic substances analyzed after background compounds removed.	IIB
90	Choi SH, Choi DH, Kang DH, et al. Activated carbon fiber filters could reduce the risk of surgical smoke exposure during laparoscopic surgery: application of volatile organic compounds. *Surg Endosc.* 2018;32(10):4290-4298.	Quasi-experimental	20 patients undergoing transperitoneal laparoscopic nephrectomy for renal cell carcinoma	application of novel multilayer filter with activated carbon filter, HEPA filter, and antiviral filter	smoke collection at 20 minutes after start of coagulation (pre), 20 min after application of novel filter (post 1) and 120 min after application of filter (post 2)	surgical smoke chemical composition	Carcinogens in surgical smoke (ie, 1,2-dichloroethane, benzene, ethylbenzene) were reduced by more than 85% using an activated carbon filter. Risk of exposure to carcinogenic compounds in surgical smoke can be reduced with the use of an activated carbon filter.	IIB
91	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. *Rom Rep Phys.* 2015;67(3):954-965.	Quasi-experimental	4 samples of fresh animal tissue	CO2 laser	n/a	chemical composition of surgical smoke	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
92	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.	Quasi-experimental	4 patients undergoing urologic surgery	electrocautery	bipolar cautery	chemical content of surgical plume	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
93	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.	Quasi-experimental	36 patients undergoing TURBT and TURP urologic procedures	resectoscope with cutting loop using electrosurgery	hypertrophic prostate vs malignant bladder tumor tissue	chemical analysis of surgical smoke	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 with filtration is needed.	IIB
94	Bratu AM, Petrus M, Patachia M, et al. Quantitative analysis of laser surgical smoke: targeted study on six toxic compounds. *Rom J Phys.* 2015;60(1-2):215-227.	Quasi-experimental	24 animal tissue samples	CO2 laser at varying photoacoustic levels	n/a	quantitative chemical analysis of surgical smoke	Acetonitrile, acrolein, ammonia, and benzene exceeding the occupational exposure limits were found in the surgical smoke produced by laser vaporization of animal tissues.	IIA

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95	Fitzgerald JEF, 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.	Quasi-experimental	10 surgical patients	electrocautery	ultrasonic device	smoke plume quantity and quality	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
96	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.	Nonexperimental	20 patients undergoing laparoscopic cholecystectomy, Poland	n/a	n/a	concentration of toxic substances in surgical smoke air samples	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.	IIIB
97	Lin YW, Fan SZ, Chang KH, Huang CS, Tang CS. A novel inspection protocol to detect volatile compounds in breast surgery electrocautery smoke. *J Formos Med Assoc.* 2010;109(7):511-516.	Nonexperimental	5 patients undergoing breast surgery	n/a	n/a	quantity of hazardous chemicals in surgical smoke; factors affecting production of chemicals in surgical smoke	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
98	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.	Quasi-experimental	30 patients undergoing mastectomy or abdominal cavity surgery	electrocautery	n/a	analysis of concentrations of ethyl benzene, phenol, styrene, toluene, xylene isomers in surgical smoke	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
99	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.	Quasi-experimental	13 surgical patients	electrosurgery	n/a	chemical composition of surgical smoke	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

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100	Lee T, Soo JC, LeBouf RF, et al. Surgical smoke control with local exhaust ventilation: experimental study. *J Occup Environ Hyg.* 2018;15(4):341-350.	Quasi-experimental	electrocautery smoke produced from 6 tissue bank samples in unoccupied operating rooms, United States	Local exhaust ventilation (LEV) with surgical smoke evacuator device and with in-line wall suction filter	background, without LEV control,	airborne particle concentration, VOC levels	LEV can reduce but not completely eliminate airborne particle levels or VOC levels from surgical smoke.	IIC
101	Tokuda Y, Okamura T, Maruta M, et al. Prospective randomized study evaluating the usefulness of a surgical smoke evacuation system in operating rooms for breast surgery. *J Occup Med Toxicol.* 2020;15:13.	RCT	62 breast procedures	smoke evacuator use (n = 30)	no smoke evacuator (n = 32)	Total volatile organic compound concentrations and formaldehyde levels	Total volatile organic compound (VOC) concentration and formaldehyde concentration were found at significantly lower levels when a smoke evacuation system was used compared to when no smoke evacuator was used. Further, smoke evacuators were found to be a significant factor in reducing formaldehyde and acetaldehyde personal exposure levels. Smoke evacuators are an effective method to decrease levels of environmental pollutants in the air during surgery.	IB
102	Yeganeh A, Hajializade M, Sabagh AP, Athari B, Jamshidi M, Moghtadaei M. Analysis of electrocautery smoke released from the tissues frequently cut in orthopedic surgeries. *World J Orthop.* 2020;11(3):177-183.	Nonexperimental	5 samples of tissue from patients undergoing knee arthroplasty	n/a	electrocautery for 4 minutes	VOC levels and PAH levels in surgical smoke	The highest number of VOCs were detected in synovial tissue and lowest number in meniscus and adipose tissue, though highest percentage of toxic/carcinogenic substances was found in muscle and meniscus tissue (toluene, ethylbenzene, and styrene). No PAHs were detected. Surgeons should avoid electrocautery of tissues containing high VOC levels such as muscle and meniscus.	IIIC
103	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.	Quasi-experimental	7 porcine tissue samples	tissue ablation	electrocautery, harmonic scalpel, and argon beam	toxins and carcinogens in aerosol byproducts of surgical smoke	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
104	Claudio CV, Ribeiro RP, Martins JT, Marziale MHP, Solci MC, Dalmas JC. Polycyclic aromatic hydrocarbons produced by electrocautery smoke and the use of personal protective equipment 1. *Rev Lat Am Enfermagem.* 2017;25:e2853.	Nonexperimental	50 abdominal surgeries using electrocautery, Brazil	n/a	n/a	polycyclic aromatic hydrocarbon (PAH) levels/concentration and observation of PPE use by HCW exposed to surgical smoke	Surgical smoke analysis found PAHs in the air (naphthalene and phenanthrene). The intraoperative team had low adherence to utilizing recommended PPE. HCW may be exposed to harmful gases containing PAHs where electrocautery is used.	IIIC
105	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.	Quasi-experimental	10 patients undergoing mastectomy	electrocautery	n/a	particle concentration and polycyclic aromatic hydrocarbon concentration in surgical smoke in breathing zone; estimated cancer risk	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 x 10-6 and for anesthesia providers to be 270 x 10-6. The use of an effective smoke evacuator is strongly suggested to diminish the hazards to surgical staff.	IIB

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106	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.	Quasi-experimental	40 patients undergoing peritonectomy	electrocautery	n/a	levels of polycyclic aromatic hydrocarbons in surgical smoke	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
107	Hui Y, Yan J. Effect of electrosurgery in the operating room on surgeons' blood indices: a simulation model and experiment on rabbits. *J Int Med Res.* 2018;46(12):5245-5256.	RCT	80 rabbits	varying levels of surgical smoke exposure (20 rabbits per group/condition)	pre/post	arterial blood levels of carbon monoxide and carbon dioxide	Surgeons should stand in an area that has lower surgical smoke contamination and manage their surgery schedule to reduce exposure.	IB
108	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.	Quasi-experimental	9 patients undergoing laparoscopic cholecystectomy	electrocautery	carboxyhemoglobin levels at the beginning, end, and day after surgery	Levels of carbon monoxide in the insufflation gas and blood levels of carboxyhemoglobin	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
109	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.	Quasi-experimental	12 patients undergoing TURP	vaporization with resectoscope and cutting loop	n/a	chemical composition of surgical smoke	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
110	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.	Quasi-experimental	6 samples of solid virus-containing agarose growth media	electrocautery applied to plates with live P22 bacteriophage virus	electrocautery applied to plates with no bacteria	presence of P22 bacteriophage in surgical smoke	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
111	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.	Quasi-experimental	3 samples of bovine cutaneous fibropapillomas positive for BPV	CO2 laser	n/a	viral content of laser plume; tumor growth analysis	Laser plume can transmit disease. Laser practitioner must minimize potential health risks especially when treating viral-induced lesions or patients with viral disease.	IIB
112	Taravella MJ, Weinberg A, May M, Stepp P. Live virus survives excimer laser ablation. *Ophthalmology.* 1999;106(8):1498-1499.	Quasi-experimental	2 12-well plate samples of human embryonic lung fibroblast cell cultures inoculated with oral polio vaccine virus	excimer laser ablation	no excimer ablation	presence of live virus	Oral polio vaccine virus can survive excimer 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

REFERENCE #	CITATION	EVIDENCE TYPE	SAMPLE SIZE/ POPULATION	INTERVENTION(S)	CONTROL/ COMPARISON	OUTCOME MEASURE(S)	CONCLUSION(S)	CONSENSUS SCORE
113	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.	Quasi-experimental	lab samples of retrovirus supernatant and wild-type NIH3Ts cells	Er:YAG Laser Beam	n/a	presence of viable cells in laser vapor	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
114	Cox SV, Dobry AS, Zachary CB, Cohen JL. Laser plume from human papillomavirus-infected tissue: a systematic review. *Dermatol Surg.* 2020;46(12):1676-1682.	Literature Review	n/a	n/a	n/a	n/a	The evidence of occupational HPV infectivity and transmission during laser ablative procedures on HPV-containing tissue is conflicting. Health care providers should use N95 or N100 surgical masks and smoke evacuation devices. Smoke evacuation tips should be placed within 1cm of the surgical site where smoke is being produced to ensure removal. Further research is needed to evaluate infectivity of surgical smoke from HPV lesions treated with laser or cautery. The authors highlight that health care providers are at high risk for HPV exposure when treating HPV lesions with lasers and should therefore consider vaccination.	VA
115	Palma S, Gnambs T, Crevenna R, Jordakieva G. Airborne human papillomavirus (HPV) transmission risk during ablation procedures: a systematic review and meta-analysis. *Environ Res.* 2021;192:110437.	Systematic Review w/ Meta-Analysis	n/a	n/a	n/a	n/a	Occupational HPV transmission risk through CO2 laser and LEEP is feasible, though infection risk remains unknown. CO2 laser ablation on HPV infected tissue creates higher risk for upper airway wart infection. Further research is needed to establish transmission estimated risk from airborne HPV during ablation procedures and confirm causal link. Occupational health goals continue to focus on minimizing occupational transmission of diseases. Healthcare workers should be allowed to manage their risk.	VA
116	Neumann K, Cavalar M, Rody A, Friemert L, Beyer DA. Is surgical plume developing during routine LEEPs contaminated with high-risk HPV? A pilot series of experiments. *Arch Gynecol Obstet.* 2018;297(2):421-424.	Nonexperimental	24 human LEEP procedures	n/a	n/a	Presence of HPV DNA in surgical smoke	Use effective suction, respiratory protection during HPV cases. Researchers propose HPV vaccination for HCW involved in LEEP cases.	IIIB
117	Zhou Q, Hu X, Zhou J, Zhao M, Zhu X, Zhu X. Human papillomavirus DNA in surgical smoke during cervical loop electrosurgical excision procedures and its impact on the surgeon. *Cancer Manage Res.* 2019;11:3643-3654.	Nonexperimental	134 women with HPV infection undergoing LEEP procedures and 31 gynecologists, China	n/a	n/a	Presence of HPV DNA in surgical smoke and nasal epithelial cells	Surgical smoke produced from LEEP procedures involving HPV infected tissue can contain HPV DNA and may be infectious. Surgical smoke evacuators and high-filtration masks should be used during LEEP procedures.	IIIB

REFERENCE #	CITATION	EVIDENCE TYPE	SAMPLE SIZE/ POPULATION	INTERVENTION(S)	CONTROL/ COMPARISON	OUTCOME MEASURE(S)	CONCLUSION(S)	CONSENSUS SCORE
118	Schultz L. Can efficient smoke evacuation limit aerosolization of bacteria? *AORN J.* 2015;102(1):7-14.	Quasi-experimental	10 porcine tissue samples embedded with Serratia marcescens	electrosurgery with blended cautery, pure coagulation, and CO2 laser	surgical smoke evacuator vs no surgical smoke evacuator	Presence of viable bacteria (Serratia marcescens) in surgical smoke and bacterial contamination of wound margins. Impact of surgical smoke evacuation on aerosolized bacteria in surgical smoke.	Surgical smoke from blended electrosurgical current can contain viable bacteria. CO2 laser or pure coagulation electrosurgery surgical smoke does not contain viable bacteria. Surgical smoke evacuators significantly decrease contamination of wounds, but cannot prevent contamination. Evacuation prevents aerosolization of bacteria.	IIB
119	Cukier J, Price MF, Gentry LO. Suction lipoplasty: biohazardous aerosols and exhaust mist—the clouded issue. *Plast Reconstr Surg.* 1989;83(3):494-499.	Quasi-experimental	9 lab samples of pseudomonas saline suspension	rotary vein aspirator	with and without filter	presence of pseudomonas aeruginosa	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
120	Nogler M, Lass-Flörl 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.	Quasi-experimental	1 human cadaver model with simulated intramedullary blood contaminated with staphylococcus aureus	simulated revision hip arthroplasty on a human cadaver model	n/a	environmental and body contamination	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
121	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.	Quasi-experimental	132 dental patients	dental extraction with high speed instruments (eg, dental turbine, air motor, micro-engine hand piece)	varying distances from the surgical site	presence of floating blood aerosols from high speed instruments	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
122	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.	Quasi-experimental	33 dental patients	oral surgery	n/a	presence of blood-contaminated aerosols	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

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123	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.	Quasi-experimental	25 bovine tissue samples	surgical techniques with 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	n/a	particle size distribution and presence of hemoglobin in aerosols	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
124	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.	Quasi-experimental	46 patients undergoing orthopedic trauma procedures	orthopedic power instrumentation and pulse lavage	n/a	Amount of blood splatter and recognition of the splatter by the surgeon	Power instrumentation produces a blood particulate mist during orthopedic surgery causing considerable microscopic, facial contamination which is a significant risk to the surgeon.	IIC
125	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.	Literature Review	n/a	n/a	n/a	n/a	Literature review examining the hazards of surgical smoke for operating room personnel. The authors concluded that surgical smoke should be removed using surgical smoke evacuation system. Surgeons should encourage the evacuation of smoke to minimize the potential health hazards to the entire perioperative team.	VB
126	Alp E, Bijl D, Bleichrodt RP, Hansson B, Voss A. Surgical smoke and infection control. *J Hosp Infect.* 2006;62(1):1-5.	Literature Review	n/a	n/a	n/a	n/a	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
127	Born H, Ivey C. How should we safely handle surgical smoke? *Laryngoscope.* 2014;124(10):2213-2215.	Literature Review	n/a	n/a	n/a	n/a	Review of best practices to reduce exposure to surgical smoke.	VB
128	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.	Literature Review	n/a	n/a	n/a	n/a	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
129	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.	Systematic Review	n/a	n/a	n/a	n/a	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

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130	Kunachak S, Sobhon P. The potential alveolar hazard of carbon dioxide laser–induced smoke. *J Med Assoc Thai.* 1998;81(4):278-282.	Quasi-experimental	10 laryngeal papilloma tissue samples	vaporization of the tissue with CO2 laser	n/a	size of smoke particles; protection evaluation of 2 types of surgical masks	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
131	NIOSH Pocket Guide to Chemical Hazards. 3rd ed. Washington, DC: US Department of Health and Human Services; 2007.	Consensus	n/a	n/a	n/a	n/a	Provides chemical hazard exposure limits.	IVA
132	Immediately dangerous to life or health (IDLH) values. The National Institute for Occupational Safety and Health. Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/idlh/intridl4.html. Reviewed October I, 2019. Accessed August 31, 2021.	Guideline	n/a	n/a	n/a	n/a	Provides immediately dangerous to life or health (IDLH) values for hazardous chemicals.	IVA
133	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.	Literature Review	n/a	n/a	n/a	n/a	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
134	Ha HI, Choi MC, Jung SG, et al. Chemicals in surgical smoke and the efficiency of built-in-filter ports. *JSLS.* 2019;23(4):e2019.00037.	Quasi-experimental	7 patients with benign uterine pathology undergoing laparoscopic or robotic surgery	electrocautery	built-in-filter port vs. nonfiltered port	chemical content of surgical smoke	Minimally invasive gynecologic surgery electrocautery surgical smoke contains hazardous chemicals including hydrocarbons and formaldehyde. Built-in filter ports can significantly reduce VOCs and some aldehyde levels in surgical smoke and reduce exposure to OR personnel. Though formaldehyde levels decreased with the use of a built-in filter port, levels remained above the NIOSH recommended formaldehyde exposure limit.	IIC
135	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.	Quasi-experimental	20 patients undergoing transperitoneal laparoscopic nephrectomy for renal cell carcinoma	CO2 laser vaporization	Japanese air quality standards	calculated cancer risk and calculated hazardous quotient	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
136	Park SC, Lee SK, Han SH, Chung YJ, Park JK. Comparison of harmful gases produced during GreenLight High-Performance System laser prostatectomy and transurethral resection of the prostate. *Urology.* 2012;79(5):1118-1124.	Quasi-experimental	36 patients undergoing urology surgery	HPS with Urosol or normal saline	TURVP with Urosol	toxic compounds in surgical smoke	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

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137	Petrus M, Matei C, Patachia M, Dumitras DC. Quantitative in vitro analysis of surgical smoke by laser photocoustic spectroscopy. *Journal of Optoelectronics and Advanced Materials.* 2012;14(7-8):664-670.	Quasi-experimental	12 fresh animal tissue samples	CO2 laser	laser power, exposure time, tissue type	levels of benzene, ethylene, ammonia, and methanol in surgical plume	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
138	Chuang GS, Farinelli W, Christiani DC, Herrick RF, Lee NCY, Avram MM. Gaseous and particulate content of laser hair removal plume. *JAMA Dermatol.* 2016;152(12):1320-1326.	Quasi-experimental	2 human subjects providing hair samples	laser hair removal with smoke evacuator use	laser hair removal with smoke evacuator use, ambient air	chemical compound measurements	Laser plume revealed 377 chemical compounds. Burning hair plume from laser use should be considered biohazard; use of smoke evacuator, appropriate ventilation, and respiratory protection recommended.	IIC
139	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.	Nonexperimental	n/a	n/a	holmium: YAG and CO2 laser; near-field and far-field	Exposure estimates of laser-generated airborne contaminants	Exposure estimate modeling of LGAC were below a level of health concern, however particulate matter and chemicals in LGAC remain a risk for medical personnel and patients.	IIIB
140	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.	Quasi-experimental	25 samples of surgical smoke during a reduction mammoplasty	electrocautery	n/a	analysis of surgical smoke	Surgical plume from electrocautery poses a potential health danger to the operating staff. 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
141	Sagar PM, Meagher A, Sobczak S, Wolff BG. Chemical composition and potential hazards of electrocautery smoke. *Br J Surg.* 1996;83(12):1792.	Quasi-experimental	6 patients undergoing colorectal surgery	electrocautery	electrocautery not applied to tissue as a control	chemical composition of surgical smoke	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
142	National Research Council. Review of the Army's Technical Guides on Assessing and Managing Chemical Hazards to Deployed Personnel. Washington, DC: The National Academies Press; 2004.	Expert Opinion	n/a	n/a	n/a	n/a	Review of technical guide on assessing and managing chemical hazards to deployed Army personnel.	VA
143	Gatti JE, Bryant CJ, Noone RB, Murphy JB. The mutagenicity of electrocautery smoke. *Plast Reconstr Surg.* 1992;89(5):781-784.	Quasi-experimental	2 mammoplasty procedures	electrocautery	n/a	mutagenicity of cells in surgical smoke	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
144	Stocker B, Meier T, Fliedner TM, Plappert U. Laser pyrolysis products: sampling procedures, cytotoxic and genotoxic effects. *Mutat Res.* 1998;412(2):145-154.	Quasi-experimental	20 porcine tissue samples	irradiation with CO2 laser	different tissue types (fat, skin, muscle, liver)	analysis of genotoxic and cytotoxic effects of laser pyrolysis	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

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145	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.	Quasi-experimental	4 porcine tissue samples	irradiation with CO2 laser	different tissue types (fat, skin, muscle, liver)	analysis of cytogenic, clastogenic, genotoxic, and mutagenic effects of laser pyrolysis	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
146	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.	Quasi-experimental	6 human muscle tissue samples and 78 porcine tissue samples	electrocautery	n/a	exposure estimates based on previously studied equivalent mutagenicity to unfiltered cigarettes	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
147	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.	Quasi-experimental	3 fresh porcine liver samples	electrocautery	helium, CO2, and air-saturated closed environments	chemical composition of surgical smoke	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
148	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.	Quasi-experimental	porcine liver tissue	electrocautery	helium vs CO2 environment	cytotoxic effects	Electrosurgery smoke in a closed anoxic environment is cytotoxic to a cultured cell line. Efficient and prompt evacuation of surgical smoke during endoscopy is needed.	IIB
149	Bhatt A, Mittal S, Gopinath KS. Safety considerations for health care workers involved in cytoreductive surgery and perioperative chemotherapy. *Indian J Surg Oncol.* 2016;7(2):249-257.	Literature Review	n/a	n/a	n/a	n/a	There is extended exposure to surgical smoke during cytoreductive surgery (CRS) with or without perioperative chemotherapy (POC) as a result of high electrocautery use. Surgical team members should employ practices to protect the surgical team against surgical smoke exposure such as managing optimal air exchanges and pressures, employing LEV, wearing appropriate PPE, and educating the surgical team.	VB
150	Sood AK, Bahrani-Mostafavi Z, Stoerker J, Stone IK. Human papillomavirus DNA in LEEP plume. *Infect Dis Obstet Gynecol* . 1994;2(4):167-170.	Quasi-experimental	49 patients undergoing loop electrosurgical excision procedure for cervical neoplasia	electrocautery	n/a	presence of viable HPV DNA in surgical smoke	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
151	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.	Quasi-experimental	3 patients with genital condylomata	CO2 laser vaporization	n/a	presence of HPV-6 DNA in biopsy specimen and in surgical plume	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

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152	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.	Quasi-experimental	110 patients with HPV genital warts	CO2 laser vaporization	n/a	viable HPV	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
153	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 Pt 1):1271-1274.	Quasi-experimental	43 adults with HPV genital warts	CO2 laser vaporization	tissue swab before and after laser vaporization	HPV DNA on mucosa and in surgical smoke; contents of surgical smoke	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
154	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.	Quasi-experimental	11 patients with genital warts	argon plasma coagulation treatment	CO2 laser treatment	operating room contamination of HPV DNA	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
155	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.	Quasi-experimental	8 patients with plantar warts	electrosurgery treatment	CO2 laser treatment	presence of papillomavirus DNA in surgical plume	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
156	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.	Quasi-experimental	4 bovine fibropapilloma tissue samples; 7 patients with plantar or mosaic verrucae	CO2 laser	various power densities	presence of intact papilloma DNA	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
157	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.	Quasi-experimental	22 patients with laryngeal lesions	CO2 laser excision	n/a	presence of HPV in the smoke vapor and tissue	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
158	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.	Quasi-experimental	7 patients with laryngeal HPV-containing warts	CO2 laser vaporization	n/a	presence of HPV in smoke plume	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

REFERENCE #	CITATION	EVIDENCE TYPE	SAMPLE SIZE/ POPULATION	INTERVENTION(S)	CONTROL/ COMPARISON	OUTCOME MEASURE(S)	CONCLUSION(S)	CONSENSUS SCORE
159	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.	Quasi-experimental	5 patients with histopathologically confirmed verrucae vulgares	Er:YAG Laser Beam	n/a	presence of HPV DNA in laser plume	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
160	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.	Quasi-experimental	10 sets of fresh recurrent laryngeal papilloma specimens	CO2 laser	untreated control counterpart specimen	viability and infectivity of papilloma virus in laser smoke	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
161	Health and safety practices survey of healthcare workers. The National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/topics/healthcarehsps/smoke.html. Updated March 30, 2017. Accessed August 30, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	Surgical smoke best practices for minimizing exposure.	VA
162	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.	Nonexperimental	314 healthcare workers employed at departments of gynecology and derma-venereology	n/a	n/a	Mucosal HPV	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
163	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.	Literature Review	n/a	n/a	n/a	n/a	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
164	Ilmarinen T, Auvinen E, Hiltunen-Back E, Ranki A, Aaltonen LM, 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.	Quasi-experimental	10 male surgical patients (5 with laryngeal papillomas; 5 with genital warts)	CO2 laser treatment	oral mucosa samples from study patients, biopsy specimens; protective equipment samples	HPV presence in tissue and oral mucosal; HPV transmission from patient to protective equipment of personnel	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

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165	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.	Quasi-experimental	10 patients with biopsy-confirmed vulvar condylomata or cervical intraepithelial neoplasia; 2 dairy cattle	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	viral viability and transmission of viral disease via CO2 laser debris	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
166	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.	Nonexperimental	570-surgeons; 5202 patients with warts/ 105,720 population of the county	n/a	n/a	HPV	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
167	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.	Quasi-experimental	20 pseudorabies virus infected tissue culture plates	excimer laser ablation	viral infected samples vs non-infected control	viral contamination	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
168	Taravella MJ, Weinberg A, Blackburn P, May M. Do intact viral particles survive excimer laser ablation? *Arch Ophthalmol* . 1997;115(8):1028-1030.	Quasi-experimental	12 cell samples inoculated with varicella-zoster virus	excimer laser ablation	non-inoculated control	presence of viable varicella-zoster virus	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
169	Capizzi PJ, Clay RP, Battey MJ. Microbiologic activity in laser resurfacing plume and debris. *Lasers Surg Med.* 1998;23(3):172-174.	Quasi-experimental	13 patients undergoing laser resurfacing	CO2 laser resurfacing	Pre-procedure air filter to two consecutive filters used for 5 minutes each after the resurfacing started	bacterial and viral presence	The potential exists for operating personnel to be exposed to viable bacteria during laser resurfacing procedures.	IIC
170	Hospital Respiratory Protection Program Toolkit: Resources for Respirator Program Administrators (DHHS [NIOSH] Publication Number 2015-117). The National Institute of Occupational Safety and Health. https://www.cdc.gov/niosh/docs/2015-117/default.html. Accessed August 30, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	Guidance with recommendations and descriptions of mandatory safety and health standards and resources specific to respiratory protection.	VA

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171	Surgical smoke evacuation. Health System Risk Management. ECRI. https://www.ecri.org/search-results/member-preview/hrc/pages/surgan17_1. Published May 16, 2018. Accessed August 30, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	Overview of surgical smoke evacuation recommendations.	VB
172	Hierarchy of controls. The National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/topics/hierarchy/. Reviewed January 13, 2015. Accessed August 30, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	Application of the NIOSH hierarchy of controls to reduce workplace hazard exposure.	VA
173	Guideline for design and maintenance of the surgical suite. In: Guidelines for Perioperative Practice. Denver, CO: AORN, Inc; 2021:51-82.	Guideline	n/a	n/a	n/a	n/a	Provides guidance for the design and maintenance of the surgical suite.	IVA
174	Romano F, Gustén J, De Antonellis S, Joppolo CM. Electrosurgical smoke: ultrafine particle measurements and work environment quality in different operating theatres. *Int J Environ Res Public Health.* 2017;14(2):137.	Quasi-experimental	10 surgical procedures (liver resection, Whipple, gallstone, skin cancer, breast) using electrosurgical tools, Sweden	n/a	unidirectional downward airflow ventilation (UDV) compared to upward displacement (UWD) ventilation	ultrafine particle (UFP) concentration	Electrosurgery creates swift increases in particle concentrations. Unidirectional downward airflow with well-designed extraction grilles may provide improved UFP contaminant removal and ventilation than upward displacement ventilation.	IIB
175	Romano F, Milani S, Gustén J, Joppolo CM. Surgical smoke and airborne microbial contamination in operating theatres: influence of ventilation and surgical phases. *Int J Environ Res Public Health.* 2020;17(15):5395.	Nonexperimental	2 operating theatres during surgical smoke producing surgical procedure, Italy	n/a	upward displacement airflow system vs. a unidirectional airflow on the operating table and peripheral mixing system/four phases of surgery (preparation, body opening, surgery, body closure)	ultrafine particles and airborne contamination	Downward unidirectional airflow with peripheral mixing systems (ie, hybrid ventilation) was more effective than upward displacement ventilation in reducing airborne contamination during various stages of surgery, although ESU use increased ultrafine particle concentrations regardless of the type of ventilation. The researchers concluded that local exhaust ventilation (eg, surgical smoke evacuation) should be used to reduce surgical smoke diffusion.	IIIB
176	Seipp HM, Steffens T, Weigold J, et al. Efficiencies and noise levels of portable surgical smoke evacuation systems. *J Occup Environ Hyg.* 2018;15(11):773-781.	Quasi-experimental	5 commercially available portable smoke evacuation systems	n/a	Two cutting angles, three unidirectional displacement flow rates	Particle elimination efficiency and noise level	Smoke evacuators are beneficial and can reduce surgical smoke up to 99% when used under optimal conditions. Noise and particle concentration are related to flow rate. Smoke evacuation should be combined with general unidirectional room ventilation and limited surgical smoke production.	IIB
177	Guideline for sterile technique. In: Guidelines for Perioperative Practice. Denver, CO: AORN, Inc; 2021:943-984.	Guideline	n/a	n/a	n/a	n/a	Provides guidance for sterile technique in the perioperative area.	IVA

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178	Guideline for team communication. In: Guidelines for Perioperative Practice. Denver, CO: AORN, Inc; 2021:1065-1096.	Guideline	n/a	n/a	n/a	n/a	Provides guidance for team communication in the perioperative area.	IVA
179	Ogg MJ, Johnstone EM. Clinical Issues–June 2017. *AORN J.* 2017;105(6):619-627.	Expert Opinion	n/a	n/a	n/a	n/a	Facility policies should identify procedures that generate a small amount of smoke where a medical-surgical vacuum system with an in-line ULPA filter could be utilized. A decision tree can be used to determine indications for surgical smoke evacuation.	VA
180	Standards of perioperative nursing practice. AORN, Inc. https://aorn.org/guidelines/clinical-resources/aorn-standards. Accessed August 30, 2021.	Consensus	n/a	n/a	n/a	n/a	The standards of perioperative nursing focus on the process of providing nursing care and performing professional role activities. These standards apply to all nurses in the perioperative setting and were developed by AORN using the American Nurses Association's (ANA) scope and standards of practice for nursing and nursing administration as the foundation.	IVB
181	Limchantra IV, Fong Y, Melstrom KA. Surgical smoke exposure in operating room personnel: a review. *JAMA Surg.* 2019;154(10):960-967.	Literature Review	n/a	n/a	n/a	n/a	Surgical smoke has been found to contain dangerous chemicals and particulate matter. No safe levels of surgical smoke exist. All surgical smoke should be evacuated, though barriers exist to using mechanical filters. More research should be done on other types of smoke filtration such as electric filters.	VB
182	Hubner M, Sigrist MW, Demartines N, Gianella M, Clavien 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.	Quasi-experimental	4 patients undergoing laparoscopic colon surgery	bipolar vessel sealing device	The detected spectra in the surgical smoke were compared to the available spectra of known toxins	contents of surgical smoke	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
183	Edelman DS, Unger SW. Bipolar versus monopolar cautery scissors for laparoscopic cholecystectomy: a randomized, prospective study. *Surg Laparosc Endosc.* 1995;5(6):459-462.	RCT	80 patients undergoing cholecystectomy	bipolar cautery (n = 40)	monopolar cautery (n = 40)	surgeon satisfaction, device cutting, tissue charring, coagulation ability, production of surgical smoke	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
184	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.	Quasi-experimental	3 bovine liver tissue samples	Activation of straight and curved blade laparoscopic ultrasonic dissectors	n/a	Surgical plume emission (laminar or turbulent) and plume settlement time between curved and straight blades	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
185	Schneider A, Doundoulakis E, Can S, Fiolka A, Wilhelm D, Feussner H. Evaluation of mist production and tissue dissection efficiency using different types of ultrasound shears. *Surg Endosc.* 2009;23(12):2822-2826.	Quasi-experimental	2 animal tissue samples	ultrasonic energy	four ultrasonic devices	mist production, dissection time, number of cuttings	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

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186	Ott DE, Moss E, Martinez K. Aerosol exposure from an ultrasonically activated (Harmonic) device. *J Am Assoc Gynecol Laparosc* . 1998;5(1):29-32.	Quasi-experimental	4 animal tissue samples	ultrasonic energy	3 tip configurations, different power settings; with and without smoke evacuation	airborne particle concentrations and sizes at various distances	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
187	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* (Baltimore). 2015;94(27):e1104.	Quasi-experimental	7 porcine tissue samples, Germany	cutting of tissue using electrocautery	feedback mode, pure-cut mode; sharp-edged Teflon-coated blades, normal shaped Teflon blades, stainless steel blades	amount of surgical smoke created by electrocautery in feedback mode and pure-cut mode	Feedback mode and Teflon blade use was associated with reduced amounts of surgical smoke during cutting.	IIB
188	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.	Quasi-experimental	5 porcine models	thulium laser	n/a	Histological effect of laser on kidney tissue and maximal depth of laser penetration into renal parenchyma	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
189	Carr MM, Patel VA, Soo JC, Friend S, Lee EG. Effect of electrocautery settings on particulate concentrations in surgical plume during tonsillectomy. *Otolaryngol Head Neck Surg.* 2020;162(6):867-872.	Quasi-experimental	36 pediatric patients who underwent tonsillectomy	electrocautery (two settings) with smoke evacuation (n = 18)	electrocautery (two settings) without smoke evacuation (n = 18)	particle count in the air sampled in breathing zone of surgeon	Lowering electrosurgery settings and use of a surgical smoke evacuator significantly decreases the number of particles in the air and exposure to surgical smoke for patients, surgeons, and operating room personnel.	IIB
190	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.	Quasi-experimental	8 porcine tissue samples, United States	CO2 laser	Holmium:YAG laser	influence of operational parameter settings on size-specific mass emission rate	Three factors of power, beam diameter, and pulse repetition of the Holmium:YAG and CO2 laser influenced generation of particulate matter. Communicating risks to clinicians and occupational health professionals will increase awareness and lead to improved control strategies that minimize or eliminate surgical smoke exposure.	IIB
191	ISO 16571:2014(en): Systems for evacuation of plume generated by medical devices. International Organization for Standardization; 2014. https://www.iso.org/obp/ui/#iso:std:iso:16571:ed-1:v1:en. Accessed August 30, 2021.	Guideline	n/a	n/a	n/a	n/a	Standards for evacuation of plume generated by medical devices.	IVA
192	Smoke evacuation systems, surgical. Device Overviews & Specifications - Comparative Data. https://www.ecri.org/components/HPCS/Pages/Smoke-Evacuation-Systems,-Surgical.aspx. Published 1/1/2020. Accessed August 31, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	Overview of smoke evacuation systems and recommendations.	VB

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193	CSA Z305.13:13 (R2020). Plume scavenging in surgical, diagnostic, therapeutic, and aesthetic settings. 2013. Canadian Standards Association. https://www.csagroup.org/store/product/Z305.13-13/. Accessed August 31, 2021.	Guideline	n/a	n/a	n/a	n/a	Guideline supporting plume scavenging in surgical, diagnostic therapeutic, and aesthetic settings.	IVB
194	ISO 29463-1:2017(en): High efficiency filters and filter media for removing particles from air—Part 1: classification, performance, testing and marking. International Organization for Standardization; 2017. https://www.iso.org/obp/ui/#iso:std:iso:29463:-1:ed-2:v1:en. Accessed August 30, 2021.	Guideline	n/a	n/a	n/a	n/a	Standards for high efficiency filters and filter media for removing particles from air.	IVA
195	Guideline for medical device and product evaluation. In: Guidelines for Perioperative Practice. Denver, CO: AORN, Inc; 2021:719-728.	Guideline	n/a	n/a	n/a	n/a	Provides guidance for medical device and product evaluation in the perioperative area.	IVA
196	Levine D, Petroski GF, Haertling T, Beaudoin T. Electrostatic precipitation in low pressure laparoscopic hysterectomy and myomectomy. *JSLS.* 2020;24(4):e2020.00051.	RCT	35 women undergoing low pressure laparoscopic hysterectomy, United States	electrostatic precipitation (ESP)	no ESP	visibility and number of interruptions	ESP can facilitate low-pressure laparoscopic hysterectomy by reducing procedural pauses and clearing the visual field.	IB
197	21 CFR 878.5050: Surgical smoke precipitator. Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=5eb8ca1702aa639c15a7186f80efad89&ty=HTML&h=L&mc=true&r=SECTION&n=se21.8.878_15050. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Surgical smoke precipitators are classified as Class II devices by the FDA. They are defined as "clearance of the visual field by precipitation of surgical smoke and other aerosolized particulate matter created during laparoscopic surgery."	n/a
198	Buggisch JR, Göhler D, Le Pape A, et al. Experimental model to test electrostatic precipitation technology in the COVID-19 era: a pilot study. *J Am Coll Surg.* 2020;231(6):704-712.	Quasi-experimental	porcine gallbladder tissue in a simulated abdominal trainer, United States	monopolar and ultrasonic energy	electrostatic aerosol precipitation (EAP) vs. continuous aerosol evacuation (CAE)	bioaerosol concentration	EAP is an efficient measure to reduce bioaerosols during laparoscopic surgery.	IIB
199	Wexner SD, Cortés-Guiral D, Gilshtein H, Kent I, Reymond MA. COVID-19: impact on colorectal surgery. *Colorectal Dis.* 2020;22(6):635-640.	Expert Opinion	n/a	n/a	n/a	n/a	Describes COVID-19 impact on colorectal surgery. The OR environment and AGPs present challenges to surgical practices. The authors present logical safe approaches to colorectal surgery during the COVID-19 pandemic.	VB
200	O'Brien DC, Lee EG, Soo JC, Friend S, Callaham S, Carr MM. Surgical team exposure to cautery smoke and its mitigation during tonsillectomy. *Otolaryngol Head Neck Surg.* 2020;163(3):508-516.	Quasi-experimental	30 pediatric patients who underwent tonsillectomy	cautery with smoke evacuator pencil (n = 12); cautery with suction (n = 9)	cautery without suction (n = 9)	chemical and aerosolized particle exposure levels	Smoke evacuator pencil cautery or cautery with suction held by an assistant reduces exposure levels to aerosolized particles.	IIB

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201	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.	Quasi-experimental	4 bovine scleral tissue samples	KTP laser vaporization	with and without smoke evacuation	amount of surgical smoke	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
202	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.	RCT	30 patients undergoing thyroid or parathyroid dissection procedures	diathermy with suction [diathermy pencil with wall-suction tubing] (n = 15)	standard diathermy equipment without suction (n = 15)	amount of surgical smoke reaching the level of the surgeon's mask measured with an aerosol monitor	Suction clearance 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 a smoke clearance system appears is recommended.	IB
203	7.4 laser generated airborne contaminants (LGAC); plume and airborne contaminants (PAC). In: ANSI Z136.3: Safe Use of Lasers in Health Care. Orlando, FL.: Laser Institute of America; 2018:36-37.	Guideline	n/a	n/a	n/a	n/a	Healthcare facilities must rely on local exhaust ventilation techniques as the first line of protection.	IVB
204	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.	Guideline	n/a	n/a	n/a	n/a	Smoke evacuator units should be used since smoke plume is carcinogenic and mutagenic and possibly contaminated with bacteria and viruses.	IVB
205	Guidelines for Environmental Infection Control in Health-Care Facilities. Recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Atlanta GA: Centers for Disease Control and Prevention; 2003. https://www.cdc.gov/infectioncontrol/pdf/guid	Guideline	n/a	n/a	n/a	n/a	Potentially hazardous exposures to healthcare workers are increasing related to indoor air-quality issues. These include aerosolized sensitizing and allergenic agents and irritants. Laser plume and surgical smoke are present potential risk to HCW. Though additional studies are required to fully understand risk, recommend aerosol containment as first line of defense.	IVA
206	EC.02.02.01: The hospital manages risks related to hazardous materials and waste. Element of performance 9. In: Comprehensive Accreditation Manual for Hospitals. Oakbrook Terrace, IL: The Joint Commission; 2021.	Accreditation	n/a	n/a	n/a	n/a	The Joint Commission requires accredited facilities to minimize risk associated with vapors/gases produced by cauterizing and laser equipment.	n/a
207	Surgical smoke evacuation. In: Standards, Guidelines, and Position Statements for Perioperative Registered Nursing Practice. 12th ed. Bath, Ontario, Canada: Operating Room Nurses' Association of Canada (ORNAC); 2015:229-231.	Position Statement	n/a	n/a	n/a	n/a	Recommendations for surgical smoke evacuation.	IVC

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208	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.	Quasi-experimental	11 sheep	exposure to laser smoke produced by vaporizing blocks of bronchial tissue	three groups: single exposure (n = 4), repeated smoke exposure (n = 7), no smoke exposure (n = 2)	presence of inflammatory cells in bronchial lavage, arterial blood gas, smoke particulate measurement	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
209	Charles K. Effects of laser plume evacuation on laser in situ keratomileusis outcomes. *J Refract Surg.* 2002;18(3 Suppl):S340-S342.	Nonexperimental	199 patient who underwent LASIK	evacuation of laser plume	no laser plume evacuation	refractive visual acuity	Evacuation of the laser plume with tubing and vacuum improved refractive and uncorrected visual acuity outcomes	IIIB
210	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.	Quasi-experimental	12 samples of tissue from patients undergoing abdominal surgery	diathermy	before electrocautery and during electrocautery	volatile organic compound content in diathermy plume	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. There is a lack of evidence of the adverse health effects from the volatile organic compounds in surgical smoke and also of the safety of breathing surgical smoke. Smoke evacuators should be used to minimize exposure risk to harmful chemicals produced by diathermy.	IIB
211	Hassan I, Drelichman ER, Wolff BG, Ruiz C, Sobczak SC, Larson DW. Exposure to electrocautery toxins: understanding a potential occupational hazard. *Prof Saf* . 2006;4:38-41.	Quasi-experimental	10 patients undergoing colorectal surgery	open surgery and laparoscopic surgery	preoperative/postoperative	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.	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
212	Golda N, Huber A, Gole H. Determining the impact of intraoperative smoke evacuation on the patient experience during outpatient surgery: a randomized controlled trial. *J Am Acad Dermatol.* 2018;78(5):1007-1009.	RCT	160 adult patients undergoing Mohs surgery, United States	use of smoke evacuation	no smoke evacuation	impact of sights, sounds and smells on their experience during dermatologic surgery	The use of an integrated surgical smoke evacuation device during dermatologic surgery improves patient experience.	IC
213	Yonan Y, Ochoa S. Impact of smoke evacuation on patient experience during Mohs surgery. *Dermatol Surg* . 2017;43(11):1363-1366.	Nonexperimental	30 patients undergoing Mohs dermatologic surgery, United States	smoke evacuation during closure	no smoke evacuation during Mohs staging	patient perception of burn odor and patient satisfaction with surgical experience	Pilot study where 100% of patients perceived burning odor during Mohs staging vs 40% of patients during closure. 66.6% of patients thought odor was unpleasant during staging vs 16.6% of patients during closure. Wall suction smoke evacuation can be used to improve patient experience.	IIIB

REFERENCE #	CITATION	EVIDENCE TYPE	SAMPLE SIZE/ POPULATION	INTERVENTION(S)	CONTROL/ COMPARISON	OUTCOME MEASURE(S)	CONCLUSION(S)	CONSENSUS SCORE
214	Perry J, Agui J, Vijayakumar R, eds. Submicron and Nanoparticulate Matter Removal by HEPA-Rated Media Filters and Packed Beds of Granular Materials. No. NASA/TM—2016–218224. Washington, DC: National Aeronautics and Space Administration; 2016.	Expert Opinion	n/a	n/a	n/a	n/a	Expert opinion on physical mechanisms and characteristics of high efficiency filtration.	VA
215	Tramontini CC, Galvão CM, Vieira Claudio C, Perfeito Ribeiro R, Trevisan Martins J. Composition of the electrocautery smoke: integrative literature review. *Rev Esc Enferm USP.* 2016;50(1):144-157.	Literature Review	n/a	n/a	n/a	n/a	Surgical smoke contains polycyclic aromatic hydrocarbons, volatile organic compounds, and volatile compounds. These chemicals present a carcinogenic and mutagenic risk to healthcare workers exposed to surgical smoke.	VB
216	Georgesen C, Lipner SR. Surgical smoke: risk assessment and mitigation strategies. *J Am Acad Dermatol.* 2018;79(4):746-755.	Literature Review	n/a	n/a	n/a	n/a	Dermatologists are exposed to hazards of laser and ESU surgical smoke. Surgeons can reduce the risks associated with surgical smoke exposure through the use of smoke evacuation and respirator use. Education on surgical smoke safety should be included in the dermatology specialty and resident curriculum.	VB
217	Ball K. Protecting patients from surgical smoke. *AORN J.* 2018;108(6):680-684.	Literature Review	n/a	n/a	n/a	n/a	Perioperative nurses can impact the use of surgical smoke evacuation for surgical team and patient protection.	VA
218	Control of smoke from laser/electrical surgical procedures. Engineering Controls Database. The National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/engcontrols/ecd/detail193.html. Reviewed November 16, 2018. Accessed August 31, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	Recommends control of smoke from laser/electrical surgical procedures through local exhaust ventilation and work practices.	VA
219	Liu N, Filipp N, Wood KB. The utility of local smoke evacuation in reducing surgical smoke exposure in spine surgery: a prospective self-controlled study. *Spine J.* 2020;20(2):166-173.	Quasi-experimental	51 spine surgeries, United States	paraincisional smoke evacuator (n = 25)	pencil tip smoke evacuator (n = 26)	average and peak ultrafine particle concentrations in surgical smoke	Local smoke evacuation techniques significantly reduce the ultrafine particle concentrations in the air during spine surgery.	IIB
220	Ott D. Smoke production and smoke reduction in endoscopic surgery: preliminary report. *Endosc Surg Allied Technol.* 1993;1(4):230-232.	Quasi-experimental	50 female patients undergoing laparoscopic procedures	laser or cautery smoke generating device	no smoke generating device	methemoglin levels	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 methemoglobin 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

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221	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.	Nonexperimental	82 patients undergoing laparoscopic cholecystectomy	n/a	preoperative/postoperative	chemical analysis of surgical smoke in the abdominal cavity; concentrations of benzene and toluene in patient's urine	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
222	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.	Quasi-experimental	6 porcine models; 10 independent surgeon evaluators	surgical smoke from high-frequency electrosurgical or laparoscopic coagulating shears	smoke evacuation vs. no smoke evacuation	field of view subjective evaluation	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
223	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.	Quasi-experimental	21 patients undergoing laparoscopic cholecystectomy and 21 surgeons performing procedure	Monopolar electrocautery in a CO2 pneumoperitoneum	preoperative/postoperative; intraperitoneal levels of carbon monoxide and systemic carboxyhemoglobin levels	Patient's level of intraabdominal carbon monoxide, systemic methemoglobin and carboxyhemoglobin, intraperitoneal hydrogen cyanide; and surgeon's levels of carboxyhemoglobin and methemoglobin	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
224	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.	Quasi-experimental	27 female patients undergoing laparoscopic surgery	surgery with surgical smoke production	preoperative/postoperative	level of carboxyhemoglobin in the blood	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
225	Hahn KY, Kang DW, Azman ZAM, Kim SY, Kim SH. Removal of hazardous surgical smoke using a built-in-filter trocar: a study in laparoscopic rectal resection. *Surg Laparosc Endosc Percutan Tech.* 2017;27(5):341-345.	Quasi-experimental	10 patients undergoing rectal cancer resection using electrocautery and ultrasonic scalpel, Korea	built-in-filter trocar (n = 5)	nonfiltered trocar (n = 5)	VOC levels and PAH levels in surgical smoke	Surgical smoke contains hazardous chemical compounds. Using disposable built-in-filter trocars can reduce VOC concentrations.	IIC
226	29 CFR 1910.1030. Bloodborne pathogens. Occupational Safety and Health Administration. https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1030. Accessed August 31, 2021.	Regulatory	n/a	n/a	n/a	n/a	Employers shall ensure an exposure control plan and engineering and work practice controls to minimize potential blood borne pathogen exposure.	n/a

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227	Respirator trusted-source information. The National Personal Protective Technology Laboratory. Centers for Disease Control and Prevention. http://www.cdc.gov/niosh/npptl/topics/respirators/disp_part/RespSource.html. Accessed August 31, 2021.	Regulatory	n/a	n/a	n/a	n/a	Provides information on the types of respirators used in the workplace, including a listing of all NIOSH-approved and FDA-cleared surgical N95 respirators. Includes OSHA respiratory protection standards.	n/a
228	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.	Quasi-experimental	10 human subjects, United States	exposure to electrocautery smoke from animal tissue	surgical mask vs surgical respirator	Simulated workplace protection factor (SWPF)	Surgical masks do not provide protection against surgical smoke particles.	IIB
229	Rengasamy S, Miller A, Eimer BC, Shaffer RE. Filtration performance of FDA-cleared surgical masks. *J Int Soc Respir Prot.* 2009;26(3):54-70.	Quasi-experimental	n/a	room air particle penetration at constant flow condition, cyclic flow condition, polydisperse aerosol penetrations, monodisperse aerosol penetrations	5 surgical masks	filtration performance	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
230	Elmashae Y, Koehler RH, Yermakov M, Reponen T, Grinshpun SA. Surgical smoke simulation study: physical characterization and respiratory protection. *Aerosol Sci Technol* . 2018;52(1):38-45.	Quasi-experimental	10 human subjects, simulation study, United States	exposure to surgical smoke from electrocautery dissection of lamb muscle	N95 NIOSH-certified particulate filtering facepiece respirators compared to the same N95 models with replaced novel faceseal technology	Simulated workplace protection factor (SWPF)	N95 modified with novel face seal technology reduced leakage around mask. Recommended for use over other commercial N95 filtering facepiece respirators for respiratory protection against surgical smoke.	IIB
231	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 Built Environ.* 2011;20(2):265-277.	Quasi-experimental	n/a	surrogate bioaerosol exposure	5 surgical masks, 3 N95 respirators, 3 surgical N95 respirators	Total inward leakage which is a function of both filter media efficiency and face seal leakage	A Collison nebulizer could generate mono-disperse bacterial aerosol from a monoculture to effectively test respiratory protection equipment total inward leakage.	IIB
232	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.	Quasi-experimental	8 participants	normal breathing, deep breathing, turning the head from side to side, flexing and extending the head, talking, and bending over.	standard mark vs laser mask vs FFP2 respirator	Particle counts inside and outside the protective device during a series of activities	FFP2 half-face respirators 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

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233	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.	Quasi-experimental	n/a	Virus aerosol delivery and ultrafine particle delivery	Two models of N99 masks and one model of N95; three different flow rates per mask	filtration	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
234	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.	Quasi-experimental	n/a	aerosol penetration	filters for full and half face respirators, disposable dust masks, disposable surgical masks	filtration performance	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
235	Chen CC, Willeke K. Aerosol penetration through surgical masks. *Am J Infect Control.* 1992;20(4):177-184.	Quasi-experimental	n/a	Exposure of masks to a test aerosol in a filter test chamber using a size-fractioning aerosol generator.	surgical masks and respirators	aerosol penetration characteristics	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
236	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.	Quasi-experimental	n/a	particle aerosolization	surgical masks with different filter media and shapes vs more protective dust-mist-fume respirator	Aerosol particle penetration of the filter media and induced face-seal leakage	The protection provided by surgical masks may be insufficient in environments containing potentially hazardous submicrometer-sized aerosols.	IIB
237	Oberg T, Brosseau LM. Surgical mask filter and fit performance. *Am J Infect Control.* 2008;36(4):276-282.	Quasi-experimental	20 participants	qualitative and quantitative fit tests	Nine surgical masks (eg, surgical , laser, cup, flat, duckbill, ties, ear loops)	Subjective facial fit and filter performance of masks	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
238	Subbarayan RS, Shew M, Enders J, Bur AM, Thomas SM. Occupational exposure of oropharyngeal human papillomavirus amongst otolaryngologists. *Laryngoscope* . 2020;130(10):2366-2371.	Nonexperimental	6 patients HPV16 undergoing transoral robotic resection of squamous cell cancers, United States	n/a	n/a	HPV presence in surgical plume	Occupational exposure to HPV16 through electrocautery surgical smoke is likely minimal.	IIIC
239	Engelman DT, Lother S, George I, et al. Adult cardiac surgery and the COVID-19 pandemic: aggressive infection mitigation strategies are necessary in the operating room and surgical recovery. *Ann Thorac Surg.* 2020;110(2):707-711.	Guideline	n/a	n/a	n/a	n/a	Guidance recommendations from the Society of Thoracic Surgeons and the American Association for Thoracic Surgery for use during elevated pandemic disease burden.	IVB

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240	Advisory Committee on Immunization Practices; Centers for Disease Control and Prevention (CDC). Immunization of health-care personnel: recommendations of the Advisory Committee on Immunization Practices (ACIP). *MMWR Recomm Rep.* 2011;60(RR-7):1-45.	Guideline	n/a	n/a	n/a	n/a	Provides guidance on immunization of healthcare personnel.	IVA
241	Derkay C. Occupational exposure to human papilloma virus (HPV) and prophylactic vaccination. US National Library of Medicine. ClinicalTrials.gov. https://clinicaltrials.gov/ct2/show/NCT03350698?term=occupational&cond=HPV&draw=2&rank=1. Published November 22, 2017. Updated August 19, 2021. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Clinical trial registry investigating occupational HPV vaccination.	n/a
242	Golda N, Merrill B, Neill B. Intraoperative electrosurgical smoke during outpatient surgery: a survey of dermatologic surgeon and staff preferences. *Cutis.* 2019;104(2):120-124.	Nonexperimental	437 dermatologic physicians and staff members	n/a	n/a	perceptions of surgical smoke	Dermatologists who perform skin surgery where surgical smoke is produced were more likely to report they were bothered by ESU smoke and more likely to prefer smoke evacuation after they were provided information on potential harms of ESU smoke. Further, dermatologists were willing to pay for smoke evacuation though expressed concern over cost and regulatory requirements.	IIIB
243	Bree K, Barnhill S, Rundell W. The dangers of electrosurgical smoke to operating room personnel: a review. *Workplace Health Saf.* 2017;65(11):517-526.	Literature Review	n/a	n/a	n/a	n/a	Surgical personnel should utilize smoke evacuation and avoid electrosurgery when possible to protect staff members.	VA
244	Swerdlow BN. Surgical smoke and the anesthesia provider. *J Anesth.* 2020;34(4):575-584.	Literature Review	n/a	n/a	n/a	n/a	Surgical smoke is an occupational hazard for operating room workers, including anesthesia providers. Anesthesia providers should advocate for effective surgical smoke safety practices.	VA
245	ECRI. Clearing the air around surgical smoke: know the risks. Health Devices. https://www.ecri.org/components/HDJournal/Pages/Clearing-the-Air-around-Surgical-Smoke.aspx#. Published July 24, 2019. Accessed August 24, 2021.	Expert Opinion	n/a	n/a	n/a	n/a	There exists a paucity of research demonstrating a direct link between surgical smoke and clinician health. Knowledge and education regarding the potential risks of surgical smoke and surgical smoke hazard evacuation strategies should be made available to clinicians.	VB
246	Chavis S, Wagner V, Becker M, Bowerman MI, Jamias MS. Clearing the air about surgical smoke: an education program. *AORN J.* 2016;103(3):289-296.	Organizational Experience	20-room operating suite in Baltimore, Maryland	n/a	n/a	n/a	A comprehensive surgical smoke education program can result in improved surgical smoke evacuation practices.	VB
247	Dobbie MK, Fezza M, Kent M, Lu J, Saraceni ML, Titone S. Operation clean air: implementing a surgical smoke evacuation program. *AORN J.* 2017;106(6):502-512.	Organizational Experience	Academic medical center, New York City	n/a	n/a	n/a	This medical center experienced successful implementation of a surgical smoke free program.	VB

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248	Tagle M. Reduction of surgical smoke in the operating room: application of the evidence. *J Pediatr Surg Nurs.* 2020;9(2):49-51	Literature Review	n/a	n/a	n/a	n/a	Evidence supports a need for implementing surgical smoke awareness and protective measures.	VC
249	York K, Autry M. Surgical smoke: putting the pieces together to become smoke-free. *AORN J* . 2018;107(6):692-703.	Organizational Experience	one hospital, North Carolina	n/a	n/a	n/a	In this organization, surgical staff education and product trials involving surgeons and staff members supported implementation of a successful surgical smoke evacuation program.	VB
250	42 CFR 482. Conditions of participation for hospitals. Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=5eb8ca1702aa639c15a7186f80efad89&ty=HTML&h=L&mc=true&r=PART&n=pt42.5.482. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Facilities must have policies and procedures in place that guide and support patient care, treatment, and services.	n/a
251	42 CFR 416: Ambulatory surgical services. Electronic Code of Federal Regulations. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=5eb8ca1702aa639c15a7186f80efad89&ty=HTML&h=L&mc=true&r=PART&n=pt42.3.416. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Facilities must have policies and procedures in place that guide and support patient care, treatment, and services.	n/a
252	State Operations Manual Appendix A: Survey Protocol, Regulations and Interpretive Guidelines for Hospitals. Rev. 200; 02-21-20. Centers for Medicare & Medicaid Services. https://www.cms.gov/Regulations-and-Guidance/Guidance/Manuals/downloads/som107ap_a_hospitals.pdf. Accessed August 31, 2021.	Regulatory	n/a	n/a	n/a	n/a	Facilities must have policies and procedures in place that guide and support patient care, treatment, and services.	n/a
253	State Operations Manual Appendix L: Guidance for Surveyors: Ambulatory Surgical Centers. Rev. 200, 02-21-20. Centers for Medicare & Medicaid Services. https://www.cms.gov/Regulations-and-Guidance/Guidance/Manuals/downloads/som107ap_l_ambulatory.pdf. Accessed August 31, 2021.	Regulatory	n/a	n/a	n/a	n/a	Facilities must have policies and procedures in place that guide and support patient care, treatment, and services.	n/a
254	Bryant CJ, Gorman R, Stewart J, Whong Z. Health hazard evaluation report: HETA-85-126-1932, Bryn Mawr Hospital, Bryn Mawr, Pennsylvania. The National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/85-126-1932.pdf. Published September 1988. Accessed August 30, 2021.	Case Report	n/a	n/a	n/a	n/a	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

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255	Moss CE, Bryant CJ, Whong Z, Stewart J. Health hazard evaluation report: HETA-88-101-2008, University of Utah Health Sciences Center, Salt Lake City, Utah. The National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/1988-0101-2008.pdf?id=10.26616/NIOSHHETA881012008. Published February 1990. Accessed August 30, 2021.	Case Report	n/a	n/a	n/a	n/a	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
256	King B, McCullough J. Health hazard evaluation report: HETA-2000-0402-3021, Inova Fairfax Hospital, Falls Church, Virginia. The National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/2000-0402-3021.pdf?id=10.26616/NIOSHHETA200004023021. Published November 2006. Accessed August 30, 2021.	Case Report	n/a	n/a	n/a	n/a	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
257	King B, McCullough J. Health hazard evaluation report: HETA-2001-0066-3019, Morton Plant Hospital, Dunedin, Florida. The National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/2001-0066-3019.pdf?id=10.26616/NIOSHHETA200100663019. Published October 2006. Accessed August 30, 2021. [VA]	Case Report	n/a	n/a	n/a	n/a	Report of concerns from surgery department employees about possible health effects from exposure to byproducts of surgical smoke in the operating room.	VA
258	King B, McCullough J. Health hazard evaluation report: HETA-2001-0030-3020, Carolinas Medical Center, Charlotte, North Carolina. The National Institute for Occupational Safety and Health. https://www.cdc.gov/niosh/hhe/reports/pdfs/2001-0030-3020.pdf. Published November 2006. Accessed August 30, 2021.	Case Report	n/a	n/a	n/a	n/a	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
259	Medical device reporting (MDR): How to report medical device problems. US Food and Drug Administration. https://www.fda.gov/medical-devices/medical-device-safety/medical-device-reporting-mdr-how-report-medical-device-problems#overview. Updated October 2, 2020. Accessed August 30, 2021.	Regulatory	n/a	n/a	n/a	n/a	Requirements for medical device reporting.	n/a