Surgical smoke: Risk assessment and mitigation strategies

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Background: Although many dermatologic surgeons are aware of the risks of surgical smoke, many do not use hazard reduction strategies.

Objective: To identify the infectious, inhalational, chemical, and mutagenic risks of surgical smoke in dermatologic procedures and suggest evidence-based hazard reduction strategies.

Methods: A review of articles indexed for MEDLINE on PubMed using the keywords *surgical smoke*, *dermatology*, *surgical mask*, *respirator*, *smoke evacuator*, and *guidelines* in 13 combinations was performed by using Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocols. The review included data from 45 articles from the dermatology, surgery, infectious disease, obstetrics, and cancer biology literature.

Results: There are risks associated with surgical smoke, and although some dermatologists are aware of these risks, many are not using hazard reduction strategies such as smoke evacuators and surgical masks.

Limitations: Most of the data regarding the hazards of surgical smoke and methods for smoke safety are derived from in vitro and in vivo studies in nonhumans, as well as from resources outside of the dermatology literature.

Conclusion: Standardized guidelines for surgical smoke safety should be implemented in the dermatology community and residency curriculum. (J Am Acad Dermatol 2018;79:746-55.)

Key words: electrosurgery; lasers; N95 mask; residency training; safety; smoke evacuator; surgical mask; surgical plume; surgical smoke; verruca.

Dermatologists regularly perform procedures that generate smoke (carbon and other particles emitted from a burning substance). In a recent study of US dermatology residency programs, more than 90% of residents received training in cosmetic procedures, including ablative lasers and electrodessication.[1] Furthermore, Accreditation Council for Graduate Medical Education (ACGME) guidelines require direct observation of at least 3 ablative laser procedures, in addition to performance of 50 excisions, before graduation. Training in smoke safety, however, is not an ACGME requirement.[2]

Surgical smoke poses numerous risks to the surgeon, including the transmission of infectious diseases, mutagenicity, and direct physical injury.[3]

Abbreviations used:

ACGME:	Accreditation Council for Graduate Medical Education
HEPA:	high-efficiency particulate air
HPV:	human papillomavirus
NIOSH:	National Institute for Occupational Safety and Health

Smoke safety guidelines would establish a safe environment for the surgeon, perioperative team, and patient.[4,5] However, standardized guidelines within the dermatology community have not yet been established. In this article, we have reviewed the potential hazards of smoke associated with

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dermatologic surgery and laser procedures and have proposed strategies to minimize risk.

METHODS

A review of articles indexed for MEDLINE on PubMed using the keywords *surgical smoke*, *dermatology*, *surgical mask*, *respirator*, *smoke evacuator*, and *guidelines* in 13 combinations was performed by using Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocols. Of the168 articles screened in the database, 59 included the topics of surgical smoke hazards or safety in the title or abstract. Of these, 17 were excluded because of inapplicability or conclusions that were not based on statistically significant data. Three additional articles were identified during the revision stages and included after the initial review. This review includes 45 articles from the literature (11 from the dermatology literature, 25 from the surgery literature, 5 from the literature on infectious disease control, 2 from the obstetrics literature, and 2 from the literature on cancer biology) (Fig 1). In addition, 6 online sources (from national and state government agency websites) were referenced for this review.

CAPSULE SUMMARY

- Dermatologists are repeatedly exposed to surgical smoke from lasers and electrosurgery.
- There are relevant infectious, direct physical, chemical, and mutagenic risks of surgical smoke.
- These risks can be minimized by use of respirator masks and smoke evacuation systems.

HAZARDS OF SURGICAL SMOKE

Dermatologic surgeons, residents, staff, and patients are exposed to infectious, direct physical, chemical, and mutagenic hazards during procedures that liberate smoke. There are also theoretical hazards of surgical smoke (Tables I-III).[6-18] Procedures utilizing ablative lasers and laser hair removal result in a heavy smoke plume (defined as averaging more than 100,000 particles per cubic centimeter).[19-22] It should be noted, however, that surgeons are also exposed to brief periods of heavy smoke during electrosurgery, implying that hazards are still present.[22]

Infectious hazards

Infectious particles in surgical smoke have been studied extensively,[6-11] and viral transmission has been demonstrated in animal studies (Tables I-III).[11] Viral DNA content seems to be higher (capable of inducing more focal transformations in cultured mouse cells) in dense ablative laser smoke than in electrocoagulation smoke.[8]

Garden et al[6] collected intralesional biopsy specimens before gathering (in a bubble chamber) vapor from 7 patients undergoing CO_2 laser treatment of plantar verrucae. Southern blot analysis isolated human papillomavirus (HPV) DNA in 6 of 7 of the biopsy specimens and 2 of 7 of the vapor samples. Ferenczy et al[7] investigated the presence of HPV DNA by using filter hybridization in 110 patients with confirmed condyloma acuminata that had been treated with CO_2 lasers. Swabs were also obtained from the ears, eyelids, and nasopharynx of the surgeons (who wore standard surgical masks) before and following laser surgery. HPV DNA was present in 65 of 110 of the smoke samples (60%) but was not detected in the orifices of the laser surgeons. Sawchuk et al[8] analyzed HPV DNA in the vapor obtained from human plantar warts treated with CO_2 laser or electrocoagulation. HPV DNA was detected in 5 of 8 laser-derived vapors and 4 of 7 electrocoagulation-derived vapors, with the DNA quantities being greater in the laser smoke. A standard surgical mask removed virtually all laser- or electrocoagulation-derived viral particles.

Gloster et al[9] evaluated the transmission of HPV in a comparative survey of 570 CO_2 laser surgeons. A total of 31 surgeons (5.4%) self-reported acquiring warts through exposure to verruca-generated smoke. Among these, 4 surgeons (13%) reported acquiring warts of the nasopharynx; this rate was significantly higher than the rate of 0.6% that was observed in the control group (patients with warts in Olmsted County in 1988-1992). Conversely, the control group had significantly higher rates of plantar and genital warts. Of note, all the surgeons who acquired nasopharyngeal lesions reported wearing standard surgical masks.

The transmissibility of other viruses, most notably HIV, is timely and relevant. Baggish et al[12] treated HIV-infected tissue culture pellets with a CO_2 laser and collected vaporous debris. HIV proviral DNA was strongly detected in the collection tubing via polymerase chain reaction. However, culture of vaporous debris from the tubing yielded p24 antigen only for up to 14 days, suggesting that viral viability was compromised after 2 weeks.

Direct physical injury

Surgical smoke has been shown to cause acute and chronic inhalational injury in animal studies (Tables I-III).[13-16] Histologic specimens of