Indian Journal of Surgery (October 2025) 87(5):839–844
https://doi.org/10.1007/s12262-025-04282-3

REVIEW ARTICLE

Surgical Smoke and Its Associated Hazards: A Review on Viral Transmission and Health Implications for Surgical Personnel

Himanshu Agrawal[1,3] · **Radhika Jain**[2] · **Usaid Ahmad**[2]

Received: 17 December 2024 / Accepted: 21 January 2025 / Published online: 31 January 2025
© Association of Surgeons of India 2025

Abstract

Surgical smoke, generated by energy-based devices like electrocautery, lasers, and ultrasonic knives, is a significant yet often overlooked hazard in operating rooms. Comprising viable pathogens, chemical residues, and approximately 95% water vapor, it can effectively carry infectious agents. The health risks associated with surgical smoke include respiratory issues, chronic bronchitis, asthma, and potential carcinogenic effects, raising concerns for operating room personnel. Despite these risks, many staff members do not consistently use protective measures, highlighting a critical gap in safety practices. This review aims to assess the current evidence on the risk of viral infections transmitted through surgical smoke and promote improved safety protocols. A systematic search was conducted using PubMed, Google Scholar, and other databases until September 2024 to identify articles and case reports associating viral infections in operating room staff with surgical plumes. The research study utilized the terms "viral transmission," surgical smoke, infection, HPV, SARS-CoV-2, hepatitis B, hepatitis C, and HIV. The review reveals the presence of HPV, SARS-CoV-2, hepatitis B, and HCV in surgical smoke produced by high-energy devices like CO2 lasers. While effective PPE and ventilation reduce transmission risks, the potential for viral transmission remains. Ongoing evaluation of surgical techniques and enhanced protective measures are essential to safeguard healthcare workers and minimize infection risks. Surgical smoke contains viable viruses like HPV, SARS-CoV-2, and hepatitis B, particularly from high-energy tools, posing risks to healthcare workers. Documented infections emphasize the need for stringent safety protocols and consistent PPE use. Ongoing research is vital to enhance protective measures and safeguard both healthcare professionals and patients.

Keywords Energy-based devices · Overlooked · Hazard · Viable · Pathogens · Protective measures · Critical gap

Introduction

Surgical smoke, generated during thermal surgical procedures such as laser surgeries, electrosurgery, and diathermy, poses significant risks to healthcare personnel [1]. It contains toxic chemicals, viable cellular debris, and pathogens, but is often overlooked in operating room safety protocols [2]. The primary chemical components include water vapor (95%), along with harmful substances like formaldehyde, cyanide, phenolic compounds, and benzene, all of which pose serious health risks. Formaldehyde and benzene are carcinogenic, while cyanide is a neurotoxin, and phenolic compounds irritate the skin and eyes [3, 4] (Table 1).

Exposure to surgical smoke can result in both short-term symptoms such as eye irritation, respiratory issues, and headaches, and long-term complications like chronic respiratory diseases and cancer [5]. In addition to these chemical hazards, surgical smoke can harbour viable pathogens, including HPV, HIV, and hepatitis, posing risks for viral transmission through the air, particularly highlighted during the COVID-19 pandemic [4, 5]. Technological solutions such as HEPA filters and activated charcoal in smoke evacuation systems can neutralize harmful components, but their adoption is still inconsistent across healthcare settings. Professional organizations like the American College of Surgeons (ACS), AORN, and the WHO advocate for smoke-free

✉ Himanshu Agrawal
himagr1987@gmail.com

[1] Department of Surgery, UCMS and GTB Hospital, New Delhi, India

[2] UCMS and GTB Hospital, New Delhi, India

[3] University College of Medical Sciences, University of Delhi, C-81, Alankrit CGHS, Shahdara, Delhi 110032, India

Table 1 Composition of surgical smoke

Constituent	Description
Volatile organic compounds	1,3 Butadiene, acetonitrile, acroiein, acetaldehyde, acrylonitrile, Ally's cyanide, benzene, benzaldehyde, crotanaldehyde, cyclehexanone, ethylbenzene, ethylene, formaldehyde, furfural, methanol, phenol, styrene, toluene
Pathogens	Human papilloma virus, human immunodeficiency virus, SARS-CoV-2, hepatitis B virus, *Serratia marcescens*
PAH	acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, chrysene, fluoranthene, fluorene, naphthalene, phenanthrene, pyrene
Particulate matter	Coarse (PM10), fine (PM2.5), Ultra-fine (PM0.1)
Chemical	Ammonia, carbon monoxide, hydrogen cyanide, hydrogen sulfide

environments and the use of evacuation systems, although adherence to guidelines remains variable.

This review aims to consolidate existing literature on the composition and health risks of surgical smoke, the potential for viral transmission, and the effectiveness of smoke evacuation technologies. It also emphasizes the need for further research into the long-term health effects of exposure and the importance of universal implementation of safety measures.

Methods

The eligibility criteria for this review included studies that met specific conditions, such as randomized controlled trials (RCTs), case reports, observational studies, and studies comparing viral loads in surgical smoke produced by various devices. Eligible participants comprised healthcare personnel and patients undergoing surgeries involving thermal devices. The studies had to focus on surgical smoke, particularly analysing viral agents like HPV, hepatitis B/C, HIV, and SARS-CoV-2. The primary outcomes of interest were the detection of viral agents or evidence of their transmission and the effectiveness of smoke evacuation systems. Only studies published in English up to September 2024 were considered. Non-human studies, non-surgical interventions, conference abstracts, letters, and comments, as well as studies that reported non-relevant outcomes, were excluded. For the database search, sources included EMBASE, Web of Science, MEDLINE (via PubMed), Google Scholar, and ScienceDirect, covering studies from the inception of each database to September 2024. A manual search of references was also conducted to supplement the findings. A comprehensive search strategy, developed with a medical librarian, used terms like "surgical smoke," "viral transmission," "HPV," "HIV," and "smoke evacuation," with Boolean operators (AND, OR) to combine terms, adjusting to each database's indexing system. Two authors independently screened titles and abstracts, and full-text articles were assessed for eligibility. Any disagreements were resolved through consensus or by consulting a third author. Data extraction covered study characteristics, surgical techniques, viral agents detected, the use of smoke evacuation systems, health outcomes, and statistical methods. The risk of bias in the included studies was evaluated using appropriate tools for each study design. For RCTs, the Cochrane Risk of Bias Tool was used, while case reports were assessed based on evidence strength and quality of reporting, and observational studies were evaluated using the Newcastle–Ottawa Scale. In total, 55 studies were initially screened, and after applying the inclusion and exclusion criteria, 15 studies were selected. Exclusions were made due to factors like non-human studies, non-surgical interventions, conference abstracts, and insufficient data on viral presence in surgical smoke (Fig. 1).

Results

HPV was the most extensively studied virus in surgical smoke, with several studies documenting its presence in smoke generated during CO2 laser surgeries. These studies consistently reported that HPV DNA was detectable in surgical smoke produced during procedures such as laser excision of warts, loop electrosurgical excision procedures (LEEP), and CO2 laser treatment of verrucae. The viral load in the smoke was particularly high in procedures involving direct tissue vaporization, such as laser excisions.

Regarding transmission, multiple case reports have confirmed that healthcare workers, including surgeons and nurses, exposed to surgical smoke during laser surgeries contracted HPV. For instance, one case report [6] described a nurse who developed laryngeal papillomatosis after prolonged exposure to CO2 laser surgeries. Another report [7] documented cases of laryngeal papillomatosis linked to CO2 laser use in the operating room. Research [8] into viral diseases transmitted by laser-generated plumes from CO2 lasers included testing laser plumes and inoculation sites, revealing that surgical plumes contained viral agents linked to fibro-papillomatosis.

Further investigation [9] into the presence of papillomavirus in vapour produced by CO2 laser treatment of verrucae also revealed viral agents associated with verrucae. Another study [10] on infectious papillomavirus in vapor from warts

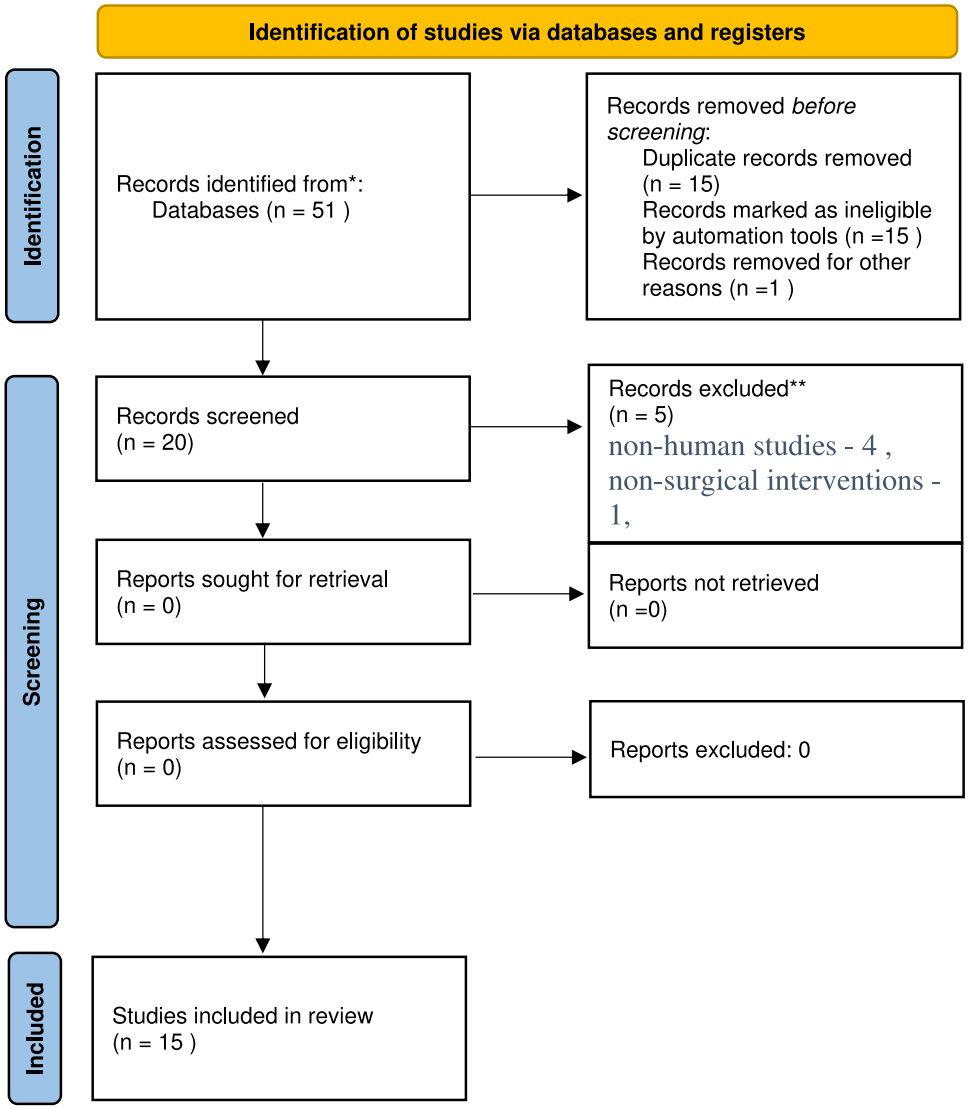


Fig. 1 PRISMA 2020 flow diagram

treated with CO2 laser and electrocoagulation found that both types of plumes contained viral agents. An analysis [11] of HPV in the plume generated during LEEP involving 49 patients with cervical intraepithelial neoplasia (CIN) showed that 39 tissue samples (80%) were HPV-positive, with types 6/11, 16/18, and 31/33/35. Additionally, surgical plume from routine LEEP procedures [12] revealed contamination with the same HPV subtype as the resected tissues, raising concerns about potential viral transmission during cervical procedures.

The effectiveness of smoke evacuation systems in mitigating risks was also highlighted. Studies demonstrated that using smoke evacuation systems, particularly those with HEPA filters, significantly reduced the presence of HPV DNA in the operating room environment. These systems were effective in trapping viral particles, thereby reducing healthcare workers' exposure to potentially infectious smoke. Table 2 and Table 3 provides a summary of the studies reporting HPV in surgical smoke. These studies share details on viral load, surgical techniques used, and the role of implementation of smoke evacuation systems.

Surgical smoke has also been implicated in the potential transmission of bloodborne viruses such as hepatitis B (HBV) and hepatitis C (HCV). Two studies provided compelling evidence of the presence of these viruses in surgical smoke.

For HBV, a meta-analysis [13] detected HBV DNA in surgical smoke, particularly during procedures utilizing high-energy devices such as electrocautery and laser surgery. The study reported a high prevalence of HBV detection, with 10 out of 11 cases testing positive for HBV using nested PCR. These findings suggest that viral particles can be aerosolized during the thermal destruction of tissue (Table 4).

In the case of HCV, a study [14] detected HCV RNA in the irrigation solution used with ultrasonic dissectors during liver surgery. The findings suggested that the use of

Table 2 Surgical smoke and HPV transmission

Study	Conclusion
Calero L et al. [6] "Laryngeal papillomatosis—first recognition in Germany as an occupational disease in an operating room nurse" Using CO2 laser in laryngeal papillomatosis	Positive healthcare worker transmission noted
Hallmo P et al. [7] "Laryngeal papillomatosis with human papillomavirus DNA contracted by a laser surgeon" using CO2 laser on laryngeal papillomatosis	Positive healthcare worker transmission noted
Garden JM et al. [8] "Viral disease transmitted by laser-generated plume (aerosol) CO2 laser plumes testing and inoculation site testing" on fibropapillomatosis	Surgical plumes contained the viral agent
Garden JM et al. [9] "Papillomavirus in the vapor of carbon dioxide laser-treated verrucae" testing CO2 laser plumes on verrucae	Surgical plumes contained the viral agent
Sawchuk WS et al. [10] "Infectious papillomavirus in the vapor of warts treated with carbon dioxide laser or electrocoagulation: detection and protection" testing CO2 laser and electro coagulation plumes on warts	Surgical plumes contained the viral agent

Table 3 Surgical smoke and HPV transmission

Study	Conclusion
Sood, A.K. et al. [11] "Human Papilloma virus DNA in LEEP plume"	Forty-nine consecutive patients with colonoscopic and cytologic evidence of cervical intraepithelial neoplasia (CIN) were tested Thirty-nine (80%) tissue samples were positive for HPV, with types 6/11 in 4, 16/18 in 19, 31/33/35 in 2, and other types in 6 patients
Neumann, K. et al. [12] "Is surgical plume developing during routine LEEPs contaminated with high-risk HPV?"	Four samples of surgical plume resulting from routine LEEPs indicated contamination with high-risk HPV and showed the same HPV subtype as identified in the resected ones

Table 4 Surgical smoke and hepatitis B transmission

Study	Conclusion
Kwak HD et al. [13], Metanalysis (hep b) on 11 cases using nested PCR	10 cases showed positive results

Table 5 Surgical smoke and hepatitis C transmission

Study	Conclusion
Higashi H et al. [14] "Detection of hepatitis C virus RNA in the ultrasonic dissector irrigating solution used in liver surgery"	Possible transmission of HCV through the irrigating solution when using the Harmonic scalpel

the harmonic scalpel, particularly in combination with contaminated irrigation fluids, could contribute to the potential transmission of HCV, especially in patients with undiagnosed HCV infections (Table 5).

The presence of HIV in surgical smoke has been investigated in several studies, yielding notable findings. One laboratory study [15] confirmed the presence of HIV in laser-generated smoke, demonstrating that the virus remained viable in smoke produced during CO2 laser procedures, thereby highlighting a potential transmission risk. Another study [16] examined the viability of HIV in cold aerosols generated by surgical power instruments, revealing that the virus could survive in aerosolized form. These findings raise concerns about potential transmission in surgical settings, especially in the absence of adequate protective measures (Table 6).

The COVID-19 pandemic raised concerns about the potential for SARS-CoV-2 transmission via surgical smoke, particularly during procedures involving aerosol-generating tools. Several studies have addressed this issue. A review [17] concluded that there was no definitive evidence of SARS-CoV-2 transmission to operating room personnel during open or minimally invasive surgeries. However, the review emphasized the importance of adhering to infection control measures throughout the pandemic. Another investigation [18] into the risk of SARS-CoV-2 transmission during

Table 6 Surgical smoke and HIV transmission

Study	Conclusion
Baggish MS et al. [15] "Presence of Human Immunodeficiency Virus DNA in Laser Smoke"	HIV DNA is present in surgical smoke
Johnson GK et al. [16] "Human immunodeficiency virus-1 (HIV-1) in the vapors of surgical power instruments."	HIV may remain viable in cold aerosols

laparoscopic surgeries found that the transmission risk via smoke and aerosols was not significantly greater than in open surgeries. In contrast, a separate study [19] detected SARS-CoV-2 RNA in surgical smoke and aerosolized fluids during abdominal surgeries, suggesting a possible route of transmission and underscoring the need for protective measures in operating rooms during the pandemic (Table 7).

The use of smoke evacuation systems is a key factor in reducing the exposure of healthcare workers to the harmful components of surgical smoke. In some studies, the use of HEPA-filtered evacuation systems led to a significant reduction in the detection of viral agents in the surgical smoke, including HPV, HBV, and HCV, [20]. Smoke evacuation systems also improved the overall air quality in the operating room, reducing the risk of respiratory distress and irritation among healthcare personnel [21].

Conclusion

This review highlights the health risks posed by surgical smoke, including the presence of viruses like HPV, HBV, HCV, HIV, and SARS-CoV-2, which can infect healthcare workers during surgery. Effective smoke evacuation systems, such as HEPA filters, can significantly reduce viral load and harmful chemicals, yet their use remains inconsistent. Challenges include gaps in smoke evacuation practices, lack of guidelines, and limited research on long-term effects of surgical smoke inhalation. Future research should focus on the health impacts of exposure, improved virus detection, and standardizing smoke evacuation protocols to enhance safety for healthcare workers and patients. Addressing these risks is crucial for occupational health and infection control.

Competing Interest

The authors declare no competing interests.

Table 7 Surgical smoke and HIV transmission SARS CoV-2 transmission

Study	Conclusions
Matta I et al. [17] "COVID-19 transmission in surgical smoke during laparoscopy and open surgery: a systematic review"	No significant difference was observed between smoke and aerosols generated from open surgery and those generated from minimally invasive surgery
Vaghef Davari F et al. [18] "Transmission Possibility of COVID-19 via Surgical Smoke Generated by the Use of Laparoscopic Approaches: A Subject of Debate During the Pandemic"	The study suggests that laparoscopic procedures do not present an increased risk of COVID-19 transmission when compared to open surgeries
Bogani G et al. [19] "Transmission of SARS-CoV-2 in Surgical Smoke during Laparoscopy: A Prospective, Proof-of-concept Study"	The study suggests SARS-CoV-2 may transmit through surgical smoke and abdominal aerosolized fluid

Acknowledgements None

Data Availability Data is available from corresponding author on request.

References

1. Benaim EH, Jaspers I (2024) Surgical smoke and its components, effects, and mitigation: a contemporary review. Toxicol Sci 198(2):157–168
2. Canicoba AR (2022) Surgical smoke and occupational health. Annals Translational Med 10(24):1303
3. McKinley IB Jr, Ludlow MO (1994) Hazards of laser smoke during endodontic therapy. J Endodontics 20(11):558–559
4. Kocher GJ, Sesia SB, Lopez-Hilfiker F, Schmid RA (2019) Surgical smoke: still an underestimated health hazard in the operating theatre. Eur J Cardiothorac Surg 55(4):626–631
5. Ulmer BC (2008) The hazards of surgical smoke. AORN J 87(4):721–738
6. Calero L, Brusis T (2003) Larynxpapillomatose-erstmalige Anerkennung als Berufskrankheit bei einer OP-Schwester. Laryngorhinootologie 82(11):790–793
7. Hallmo P, Naess O (1991) Laryngeal papillomatosis with human papillomavirus DNA contracted by a laser surgeon. Eur Arch Otorhinolaryngol 248:425–427
8. Garden JM, O'Banion MK, Bakus AD, Olson C (2002) Viral disease transmitted by laser-generated plume (aerosol). Arch Dermatol 138(10):1303–1307
9. Garden JM, O'Banion MK, Shelnitz LS, Pinski KS, Bakus AD, Reichmann ME, Sundberg JP (1988) Papillomavirus in the vapor of carbon dioxide laser-treated verrucae. JAMA 259(8):1199–1202
10. Sawchuk WS, Weber PJ, Lowy DR, Dzubow LM (1989) Infectious papillomavirus in the vapor of warts treated with carbon dioxide laser or electrocoagulation: detection and protection. J Am Acad Dermatol 21(1):41–49
11. Sood AK, Bahrani-Mostafavi Z, Stoerker J, Stone IK (1994) Human papillomavirus DNA in LEEP plume. Infect Dis Obstet Gynecol 2(4):167–170
12. Neumann K, Cavalar M, Rody A, Friemert L, Beyer DA (2018) Is surgical plume developing during routine LEEPs contaminated with high-risk HPV? A pilot series of experiments. Arch Gynecol Obstet 297:421–424
13. Kwak HD, Kim SH, Seo YS, Song KJ (2016) Detecting hepatitis B virus in surgical smoke emitted during laparoscopic surgery. Occup Environ Med 73(12):857–863
14. Higashi H, Matsumata T, Hayashi J, Yanaga K, Shimada M, Shirabe K, Taketomi A, Kashiwagi S, Sugimachi K (1994) Detection of hepatitis C virus RNA in the ultrasonic dissector irrigating solution used in liver surgery. Journal of British Surgery 81(9):1346–1347
15. Baggish MS, Polesz BJ, Joret D, Williamson P, Refai A (1991) Presence of human immunodeficiency virus DNA in laser smoke. Lasers Surg Med 11(3):197–203
16. Johnson GK, Robinson WS (1991) Human immunodeficiency virus-1 (HIV-1) in the vapors of surgical power instruments. J Med Virol 33(1):47–50
17. Matta I, Lagana AS, Ghabi E, Bitar L, Ayed A, Petousis S, Vitale SG, Sleiman Z (2022) COVID-19 transmission in surgical smoke during laparoscopy and open surgery: a systematic review. Minim Invasive Ther Allied Technol 31(5):690–697
18. VaghefDavari F, Sharifi A (2021) Transmission possibility of COVID-19 via surgical smoke generated by the use of laparoscopic approaches: a subject of debate during the pandemic. J Laparoendosc Adv Surg Tech 31(10):1106–1113
19. Bogani G, Ditto A, De Cecco L, Lopez S, Guerrisi R, Piccioni F, Micali A, Daidone MG, Raspagliesi F (2021) Transmission of SARS-CoV-2 in surgical smoke during laparoscopy: a prospective, proof-of-concept study. J Minim Invasive Gynecol 28(8):1519–1525. https://doi.org/10.1016/j.jmig.2020.12.026
20. Watters DA, Foran P, McKinley S, Campbell G (2022) Clearing the air on surgical plume. ANZ J Surg 92(1–2):57–61
21. Razdan S, Ucpinar B, Okhawere KE, Badani KK (2023) The role of AirSeal in robotic urologic surgery: a systematic review. J Laparoendosc Adv Surg Tech 33(1):21–31

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.