Research Article
Volume 16:4, 2020
DOI: 10.37421/jos.2020.16.16

Journal of Surgery [Jurnalul de chirurgie]

ISSN: 1584-9341 Open Access

Surgical Smoke-Do We Know Enough About It?

Asad Abbas[1*], Sehrish Altaf[2], Farrukh Javeed[2], Muhammad Sohail Umerani[3] and Syed Raza Khairat Rizvi[2]

[1]*Department of Neurosurgery, Nottingham University Hospital-Queen's Medical Center, Nottingham, UK*

[2]*Department of Neurosurgery, Jinnah Postgraduate Medical Centre, Rafiqui Shaheed Road, Karachi, Pakistan*

[3]*Department of Neurosurgery, King Fahd Military Medical Centre, Dhahran, Eastern Province, Saudi Arabia*

Abstract

Surgical smoke is a dangerous by-product generated from the use of surgical energy based devices. Medical personnel have always been exposed to surgical smoke, most of them unknowingly and this has accounted for several health risks consequently. There is enough literature to back the claim of surgical smoke to be hazardous towards the patients and the medical personnel involved in patients' care. The objective of this article is to assess the current awareness level among medical personnel regarding the hazards of surgical smoke, and what measures they take to minimize the risk of exposure. A total of 440 respondents, working in a operating room, between ages 22-55 years filled the questionnaire among which 300 (68.2%) work in public hospitals while 140 (31.8%) work under private setups. Although many of the respondents believed that surgical smoke was harmful, adequate measures were not taken to tackle this health hazard.

Keywords: Surgical smoke • Knowledge • Plume

Introduction

Surgical smoke, also known as plume, diathermy plume, cautery smoke, aerosols, and vapors, is a dangerous by-product generated from the use of lasers, electro surgery, ultrasonic scalpel and other surgical energy based devices. Surgical smoke is a product of interaction between the tissue and heat-emitting instrument resulting in vaporization of that tissue that produces the plume of smoke.

Medical personnel such as surgeons and Operation Theatre (OT) assistants have always been exposed to surgical smoke, most of them unknowingly and this has accounted for several health risks consequently. Surgical smoke causes technical, physical, and occupational health problems. This exposure to surgical smoke has increased over the years as electro-surgery has made its way much more extensively into many invasive surgical procedures. There is enough literature to back the claim of surgical smoke to be hazardous towards the patients and the medical personnel involved in patients' care. In fact, surgical smoke has been shown to be cytotoxic, genotoxic and mutagenic [1].

One hazardous health risk is that surgical smoke contains carcinogenic volatile molecules such as acrylonitrile (a precursor of cyanide) and carbon monoxide [2]. It has also shown to be a vector for bacteria and viruses, thus exposing surgical staff and surgeons to the risk of infection [2]. Surgical smoke contains harmful particles that have tendency to penetrate the defense mechanisms of upper respiratory tract and enter the alveoli, as well as systemic circulation, thus carrying an increased risk of respiratory diseases and strokes [2]. One obvious challenge to the surgeon is the visual obfuscation that can obstruct the surgeon's view of the surgical site particularly in laparoscopic surgery [2]. In response to the concerns raised by these hazards, commercial smoke evacuation systems (local exhaust ventilation) and high filtration masks (N95 surgical masks) have been designed to greatly reduce the number of hazardous particles as well as noxious odor produced by electro surgery and laser surgery. Promoting surgical smoke safety has been a great challenge due to the cost of both N95 grade masks and even though the risks of surgical smoke are acknowledged, smoke evacuation units are not yet routinely used in many healthcare centers [3].

The objective of this article is to assess the current awareness level among medical personnel regarding the hazards of surgical smoke, and what measures they take to minimize the risk of exposure. This will provide insight to the health care providers, who spend majority of their time in operating theaters.

Methods

The study was conducted to assess the level of awareness of surgical smoke amongst personnel working in operation theaters. Pre-designed questionnaire was filled after verbal consent. The participants included consultant surgeons, residents, house officers and operation room technicians of major tertiary care hospitals all over Karachi, Pakistan. The Questionnaire tested mainly the/level of awareness regarding sources, risks, safety practices and precautionary measures in addition to standard methods employed at their hospital. Statistical analysis was done using SPSS version-23. Mean and standard deviation were calculated for quantitative variables. Frequencies and percentages were calculated for qualitative variables. Data was stratified to compare knowledge amongst different groups.

Result

A total of 440 respondents, working in a operating room, between ages 22-55 years filled the questionnaire among which 300 (68.2%) work in government hospitals while 140 (31.8%) work under private setups. Among them 224 (50.9%) were males and 216 (49.1%) were females.

These respondents predominantly include 192 (43.6%) house officers and 150 (34.1%) postgraduate trainees while only 40 (9.1%) were consultant surgeons among them and 54 (12.3%) were operating room technicians and others (0.9%). Almost half (n=200, 45.5%) of these respondents were working in General surgery department while rest of them were working under other specialities (Table 1). Their year of experience is shown in Table 2.

***Address for Correspondence:** Asad Abbas, Department of Neurosurgery, Nottingham University Hospital-Queen's Medical Center, Nottingham, UK, E-mail: Asad.abbas@live.com*

Received 23 September 2020; **Accepted** 15 October 2020; **Published** 23 October 2020

Table 1. Surgical specialty of responders.

	Frequency	Percent
General surgery	200	45.5
Max face	2	0.5
ENT	12	2.7
Ophthalmology	6	1.4
Anesthesia	20	4.5
Orthopedics	34	7.7
Neurosurgery	38	8.6
Vascular surgery	16	3.6
Plastic surgery	30	6.8
Gyne	48	10.9
Peads surgery	6	1.4
Urology	10	2.3
Cardiac surgery	12	2.7
Other	2	0.5
Total	440	100

Table 2. Experience in years of participants.

Years of experience	Frequency	Percent
<5 yr	166	37.7
6-10 yr	208	47.3
11-15 yr	36	8.2
>15 yr	30	6.8
Total	440	100

About 182 (41.4%) respondents reported that they attend of 6-10 surgeries per week while 110 (25%) reported 11-15 surgeries/week, 74 (16.8%) reported 1-5 surgeries/week, 50 (11.4%) reported more than 20 surgeries/week and 24 (5.5%) reported 15-20 surgeries/week. Majority of them spent between 11 to 20 hours in operating rooms per weeks (Table 3).

Table 3. Number of hours spent by participants in operating room per week.

Hours spent in operating room	Frequency	Percent
<10 h	80	18.2
11-20 h	202	45.9
21-30 h	92	20.9
31-40 h	22	5
>40 h	44	10
Total	440	100

The respondents were asked about the term surgical smoke and only 18 (4.1%) were completely familiar with the term while 72 (16.4%) knew most about it, 164 (37.3%) didn't know much about it, 102 (23.2%) has heard the term but were not sure of the meaning and 84 (19.1%) had not heard the term before. When they were asked to define the term 398 (90.5%) marked the correct definition that it is a smoke produced during surgery by coagulation/cauterization of human tissue.

When asked about the different sources of surgical smoke, 380 (86.4%) thought monopolar diathermy can be a source while 350 (79.5%) thought bipolar diathermy, 182 (41.4%) thought operative laser, 136 (30.9%) thought harmonic scalpel and 124 (28.2%) thought operative drill can be a source too. However 70 (35.9%) thought nitrogen oxide cylinders, 60 (13.6%) thought that a poor handling of viscera and 34 (7.7%) thought that assistants smoking in operating rooms can also be a potential source of surgical smoke generation.

Majority (n=334, 75.9%) of respondents believe that surgical smoke is harmful while in terms of its risks and hazards only 28 (6.4%) believe that it can be a source of HIV transmission while only 50 (11.4%) thought it can be vector for Hepatitis B transmission. Seventy percent (n-308) thought that it carry a potential risk of asthma when inhaled while 288 (65.5%) believe it can cause chronic bronchitis and 196 (44.5%) thought that it carries risk for developing emphysema too. response to the contents of surgical smoke are shown in Table 4.

Table 4. Response regarding contents of surgical smoke.

	Frequency	Percent
Carbon dioxide	266	60.50
Carbon monoxide	306	69.50
Hydrogen cyanide	128	29.10
Formaldehyde	116	26.4
Phenol	112	25.50
Benzene	108	24.5
Ozone	56	12.7

While majority (75.9%) of respondents believe it is harmful only 104 (23.6%) reported clearing surgical smoke in operating rooms and more than half (52.3%, n=230) of them reported never clearing it away while only 106 (24.1%) reported clearing it only occasionally. When asked regarding their knowledge about reason behind clearing it about half of the responders cleared it so as to achieve a clear visual field during surgery (Table 5). When inquiring regarding the kind of clearing techniques they use, 208 (47.3%) reported using suction catheters or nozzles during surgery while 70 (15.9%) ventilate the smoke by opening laparoscopic ports, 34 (7.7%) reported using smoke evacuators and only 24 (5.5%) reported using specific laparoscopic smoke evacuators.

Table 5. Reasons for clearing surgical smoke (n=228).

	Frequency	Percent
Clear visual field	112	25.5
Bad odour	78	17.7
Health Hazard	36	8.2
OT protocol	2	0.5
Total	440	100

Table 6. Symptoms experienced due to exposure to surgical smoke.

	Frequency	Percent
Headache	116	26.4
Burning sensation in throat	56	12.7
Rhinitis	64	14.5
Eye irritation	92	20.9
Cough	172	39.1
Discomfort due to smell	144	32.7
Sneezing	60	13.60
Nausea/vomiting	26	5.9
Dizziness	20	4.5
Lacrimation	42	9.5
Skin rash/dermatitis	6	1.4

More than half 200 (59.1%) of the respondents reported that adequate measures had not been taken to protect them from surgical smoke. Majority (63.6%, n=280) believed that standard surgical masks are not adequate to protect them against potential hazards of surgical smoke. Two hundred and eighty two (64.1%) thought that standard wall mounted suctions do not clear smoke adequately. Three hundred and seventy-eight (85.9%) agreed on the fact that surgical smoke is not a harmless by-product of electrosurgery and laser surgery while 300 (68.2%) of them indicated concern that potential laser surgery while 300 (68.2%) of them indicated concern that potential

carcinogens are present in smoke. Three hundred and seventy-two (84.5%) believed that more evidence is required to establish the hazards of surgical smoke. Three hundred and thirty-eight (76.8%) thought that increasing diathermy voltage results in more hazardous smoke formation. Two hundred and ninety eight believed that observers are at similar risks as surgeons. Responses to the symptoms experienced by them due to exposure to surgical smoke are shown in Table 6.

While assessing the knowledge between private and government institutions, about 120 (85.7%) from private and 278 (92.6%) from government setup correctly defined the term the surgical smoke as a smoke produced during surgery by coagulation or cautery of human tissue. Replying to the query regarding different sources of surgical smoke 120 (85.7%) from private while 260 (86.6%) from government thought monopolar diathermy as a source, 94 (67.1) from private while 256 (85.3%) from government thought bipolar diathermy as a source, 2 (1.42%) from private while 58 (19.3%) from government thought that poor handling of viscera can be a source, 32 (22.8%) from private while 92 (30.6%) from government thought that operative drill can be a source, 22 (15.7%) from private while 48 (16%) from government thought nitrous oxide cylinders as a source, 10 (7.14%) from private while 24 (8%) from government thought that assistants smoking in operating room can be a source, 24 (17.1%) from private while 158 (52.6%) from government thought operative laser can be a source and 36 (25.7%) from private while 100 (33.3%) thought harmonic scalpel as a source of smoke. When inquired regarding the dangers of surgical smoke about 94 (67.1%) from private while 240 (80%) from government setup believed surgical smoke as a harmful by product. Despite of concern regarding its harmfulness only 28 (20%) from private while 18 (6%) from government setup are satisfied with adequate measures being taken in their setups to deal with its hazards.

When asked to define surgical smoke 34 (85%) consultants, 144 (96%) postgraduates, 174 (90.6%) house officers and 42 (77.7%) operating room technicians responded correctly. Only 18 (45%) consultants, 42 (28%) postgraduates, 20 (10.4%) house officers while only 8 (14.8%) operating room technicians were familiar with term previously. Twenty-six (65%) consultants, 116 (77.3%) postgraduates, 152 (79.1%) house officers and 36 (66.6%) technicians believed surgical smoke as a harmful by-product.

When assessing the knowledge between male and female respondents, about 192 (85.7%) males while 206 (95.3%) females defined the term surgical smoke correctly. When asked about the familiarity with the term surgical smoke 58 (25.8%) males while 32 (14.8%) females were previously familiar with the term. About 160 (71.4%) males and 174 (80.5%) females believed surgical smoke as a harmful by-product.

Discussion and Conclusion

Surgical smoke is generated during surgical procedures by use of lasers or electrosurgical devices from thermal destruction of tissue [1]. This study is focused on level of awareness regarding surgical among medical personnel working in operation theaters. Surgical smoke contains harmful organic compounds and carcinogens such as acrylonitrile, carbon monoxide, polyaromatic hydrocarbons, benzene, hydrogen cyanide and formaldehyde [4,5]. In a study conducted by Moot et al., showed that surgical plumes may contain as much as 3 ppm-51 ppm hydrogen cyanide, 2 ppm-8 ppm acetylene and 0.15 ppm-0.69 ppm 1,3-butadiene [6]. Another study conducted in 2013, found that the surgical smoke generated from 1 g of tissue had the mutagenic potential of smoking six unfiltered red cigarettes [7]. A study conducted by al Al Sahaf OS et al., reported thermal decomposition of adipose tissue generates aldehydes in higher concentration with generation of toluene at lower concentrations. In contrast, electro cauterization of epidermal tissue yields higher concentrations of toluene, ethyl benzene and xylene [8].

Surgical smoke has shown to contain pathogens including viruses and bacteria rendering it a major risk of infection. A study conducted by Chowdhury KK et al., reported presence of live multi-drug resistant *Mycobacterium tuberculosis*, viral DNA of HBV, HCV, HIV and HPV in smoke produced at low temperatures [9]. Another study identified the presence of viral DNA in surgical smoke [10].

In addition, benzene, toluene, ethyl benzene, and xylene in smoke irritate the skin, eyes, and respiratory tract and can cause neurotoxic symptoms such as drowsiness, headache, tremor, dizziness and coma [11]. Potential harm to patients due to smoke is another alarming concern. A study showed significant levels of benzene and toluene in patients' urine after laparoscopic cholecystectomies [12]. The smoke itself consists of particles which are able to penetrate the linings of upper respiratory tract and enter into alveoli and into the systemic circulation. In a study conducted on animal models has shown to induce acute and chronic inflammatory changes in respiratory tract [13].

Number of particles and contents in the surgical smoke varies according to type of surgery performed and largely depends on type of electro cautery used and type of tissue coagulated. A study conducted in 2018 on porcine reported highest number of particles being generated by liver followed by renal tissues and skeletal muscle producing a medium concentration of particles while subcutaneous fat, lung tissue, bronchus, cerebral gray and white matter and skin produce comparatively less number of particles [2]. Another study conducted by Bruske-Hohlfeld et al. reported large mass of particles being generated from a liver hemangioma [14].

In response to risks and hazards regarding smoke, smoke evacuation systems have been designed. The standard surgical mask is not protective enough due to leakages around mask or the tendency of small particles to not filter out [15,16]. It is recommended to use special N95 surgical masks and specialized smoke evacuators to protect OT personnel against the potential hazards from surgical smoke. Food and Drug Administration (FDA) approved surgical mask for protection against microorganisms, body fluids, and large particles greater than 5 μm in size. National Institute for Occupational Safety and Health (NIOSH) and FDA approved a surgical N95 mask as it filters at least 95% of airborne particles. An N95 should be fit tested to a specific sized mask of the wearer to ensure an adequate face seal. N95 masks have also been shown to provide protection against easily transmissible infectious pathogens including Mycobacterium tuberculosis [17]. An N100 respirator has a higher level of efficiency as N95 but is not as practical for use in the Operating rooms due to its exhalation valve components [18].

A UK based survey in Wessex, England on surgical smoke practices in 111 respondents reported approximately 52% of surgeons and 67% of surgeons-in-training used any type of LEV during diathermy procedures. Wall suction was most common, with some use of laparoscopic smoke extractors/filters [19]. Our study revealed that only 7.7% use smoke evacuators and 5.5% reported using specific laparoscopic smoke evacuators. Majority (89.5%) respondents denied having adequate measures taken in their setting to protect against hazards of plume. A study showed that the cost of both N95 grade masks and smoke evacuation systems are obstacles to promoting surgical smoke safety. A huge cost difference has been seen between N95 masks and standard surgical masks. For instance a 3 M National Institute of Occupational Safety and Health-approved N95 surgical respirator costs about $1 compared with $0.08 per standard surgical mask [3]. Surgical smoke evacuators typically cost more than $1500 per unit with lifetime maintenance costs, and an expertise to operate the system might be required [3].

In terms of assessing knowledge about risks and hazards of surgical smoke, this study shows that 75.9% respondents believed that it's a harmful by product while only 6.4% and 11.4% showed their concerns regarding HIV transmission and hepatitis B transmission respectively. In contrast a study conducted in 2017 on US dermatology showed that 71.9% of their residents did not receive any formal education on hazards of electro surgery but despite any formal education 76.5% US residents were concerned about transmission of infectious diseases via surgical smoke [3]. In another study conducted in gynecologists, 49% and 44% of survey respondents reported that they never had training on the hazards of surgical smoke in laser surgery and electro-surgery, respectively [20]. In the study conducted on US dermatologists showed that 71.9% were concerned regarding carcinogenic effects of smoke [3]. A mitigating trend is noted in this study which indicated that only 68.2%

of respondents were concerned regarding potential carcinogens present in smoke.

Despite potential hazards of smoke, the study conducted in US reported that almost three fourth of the residents believed that adequate measures were not being taken to protect them from surgical smoke [3]. This study showed that only 10.5% believed that adequate safety measures are being taken while 59.1% denied of adequate measures being taken and 30.5% were not sure that whether safety measures are being taken or not in their setups.

References

1. Barrett, William L., and Shawn M. Garber. "Surgical Smoke: A Review of the Literature." *Surg Endosc* 17 (2003): 979-987.
2. Karjalainen, Markus, Anton Kontunen, Sampo Saari, and Topi Rönkkö, et al. "The Characterization of Surgical Smoke from Various Tissues and its Implications for Occupational Safety." *PloS One* 13 (2018): e0195274.
3. Chapman, Lance W., Dorota Z. Korta, Patrick K. Lee, and Kenneth G. Linden. "Awareness of Surgical Smoke Risks and Assessment of Safety Practices during Electrosurgery among US Dermatology Residents." *JAMA Dermatol* 153 (2017): 467-468.
4. Steege, Andrea L., James M. Boiano, and Marie H. Sweeney. "Secondhand Smoke in the Operating Room? Precautionary Practices Lacking for Surgical Smoke." *Am J Indust Med* 59 (2016): 1020-1031.
5. Choi, Seock Hwan, Tae Gyun Kwon, Sung Kwang Chung, and Tae-Hwan Kim. "Surgical Smoke May be a Biohazard to Surgeons Performing Laparoscopic Surgery." *Surg Endosc* 28 (2014): 2374-2380.
6. Moot, Andrew R., Katherine M. Ledingham, Paul F. Wilson, and Senti T. Senthilmohan, et al. "Composition of Volatile Organic Compounds in Diathermy Plume as Detected by Selected Ion Flow Tube Mass Spectrometry." *ANZ J Surg* 77 (2007): 20-23.
7. Khajuria, Ankur, Mahiben Maruthappu, Myura Nagendran, and Joseph Shalhoub. "What about the Surgeon?" *Internat J Surg* 11 (2013): 18-21.
8. Al Sahaf, O.S., I. Vega-Carrascal, F.O. Cunningham, and J.P. McGrath, et al. "Chemical Composition of Smoke Produced by High-Frequency Electrosurgery." *Irish J Med Sci* 176 (2007): 229-232.
9. Chowdhury, K.K., S.M. Meftahuzzaman, D. Rickta, and T.K. Chowdhury, et al. "Electrosurgical Smoke: A Real Concern." *Mymensingh Med J* 20 (2011): 507-512.
10. Christie, D., P. Jefferson, and D.R. Ball. "Diathermy Smoke and Human Health." *Anesthesia* 60 (2005): 632-632.
11. Abbate, C., C. Giorgianni, F. Munao, and R. Brecciaroli. "Neurotoxicity Induced by Exposure to Toluene." *Internat Arch Occupat Environ Health* 64 (1993): 389-392.
12. Dobrogowski, Miłosz, Wiktor Wesołowski, Małgorzata Kucharska, and Andrzej Sapota, et al. "Chemical Composition of Surgical Smoke formed in the Abdominal Cavity during Laparoscopic Cholecystectomy-Assessment of the Risk to the Patient." *Internat J Occupat Med Environ Health* 27 (2014): 314-325.
13. Baggish, Michael S., and Mohammed Elbakry. "The Effects of Laser Smoke on the Lungs of Rats." *Am J Obstet Gynecol* 156 (1987): 1260-1265.
14. Brüske-Hohlfeld, Irene, Gerhard Preissler, Karl-Walter Jauch, and Mike Pitz, et al. "Surgical Smoke and Ultrafine Particles." *J Occupat Medicine Toxicol* 3 (2008): 1-6.
15. Hinds, William C. "Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles." *John Wiley and Sons* (1999).
16. Redmayne, A.C., D. Wake, R.C. Brown, and B. Crook. "Measurement of the Degree of Protection Afforded by Respiratory Protective Equipment against Microbiological Aerosols." *Annals Occupat Hygiene* 41 (1997): 636-640.
17. Qian, Yinge, Klaus Willeke, Sergey A. Grinshpun, and Jean Donnelly, et al. "Performance of N95 Respirators: Filtration Efficiency for Airborne Microbial and Inert Particles." *Am Industr Hygiene Assoc J* 59 (1998): 128-132.
18. Gao, Shuang, Richard H. Koehler, Michael Yermakov, and Sergey A. Grinshpun. "Performance of Facepiece Respirators and Surgical Masks against Surgical Smoke: Simulated Workplace Protection Factor Study." *Annals Occupat Hygiene* 60 (2016): 608-618.
19. Spearman, John, George Tsavellas, and Paul Nichols. "Current Attitudes and Practices Towards Diathermy Smoke." *Annals Royal College Surgeons Eng* 89 (2007): 162-165.
20. Liu, Yi, Yizuo Song, Xiaoli Hu, and Linzhi Yan, et al. "Awareness of Surgical Smoke Hazards and Enhancement of Surgical Smoke Prevention among the Gynecologists." *J Cancer* 10 (2019): 2788.

How to cite this article: Abbas, Asad, Sehrish Altaf, Farrukh Javeed, and Muhammad Sohail Umerani, et al. "Surgical Smoke-Do We Know Enough About It?" *J Surg* 16 (2020): 16. doi: 10.37421/jos.2020.16.16