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Quality of Air in the Operating Room: Surgical Smoke-A Descriptive Study

Ameliyathanenin Hava Kalitesi: Cerrahi Duman-Tanımlayıcı Bir Çalışma

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ABSTRACT Objective: Electrosurgery is used in almost all surgeries. The entire surgical team working in these operating rooms is exposed to surgical smoke. In the literature, there is no study examining the direct effect of surgical smoke on operating room staff and involving the entire surgical team in sampling. This study aimed to examine the operating room air quality due to surgical smoke. **Material and Methods:** This descriptive study was conducted in August 2018 in the operating room of the department of general surgery of a university hospital. Air samples were taken from different parts of the operating room during surgery, and levels of volatile organic compounds in the breathing zone of the surgical team were measured. **Results:** Volatile organic compounds were not detected in the air samples taken during the surgery. The measured levels were well below the limits that could affect human health. Levels of some volatile organic compounds in the breathing zone of the surgical team were above the limit. Benzene levels in the breathing zone of the surgical resident, scrub nurse, circulating nurse and support staff were above the normal limit, and the chloroform level of the support staff was above the normal limit. **Conclusion:** Levels of some volatile organic compounds in the surgical smoke from the breathing zone of operating room health care professionals were above the normal limit. It is recommended to establish a protocol for protection from surgical smoke in operating rooms and to take the necessary measures.

Keywords: Volatile organic compounds; operating rooms; air pollution (indoor); occupational health

ÖZET Amaç: Elektrocerrahi neredeyse tüm ameliyatlarda kullanılmaktadır. Bu ameliyathanelerde çalışan ekibin tamamı cerrahi dumana maruz kalmaktadır. Literatürde cerrahi dumanın ameliyathane personeli üzerine doğrudan etkisini inceleyen ve tüm cerrahi ekibi örneklemeye dâhil eden bir çalışmaya rastlanmamıştır. Bu çalışmada, cerrahi dumana bağlı ameliyathane hava kalitesinin incelenmesi amaçlanmıştır. **Gereç ve Yöntemler:** Tanımlayıcı tipteki bu çalışma, 2018 yılı Ağustos ayında bir üniversite hastanesinin genel cerrahi ana bilim dalı ameliyathanesinde yapılmıştır. Ameliyat sırasında ameliyathanenin farklı yerlerinden hava örnekleri alındı ve ameliyathane ekibinin solunum alanı içinden alınan örneklerde uçucu organik bileşiklerin seviyeleri ölçülmüştür. **Bulgular:** Ameliyat sırasında ameliyathanenin farklı yerlerinden alınan hava örneklerinde uçucu organik bileşiklere rastlanmamıştır. Ölçülen seviyeler, insan sağlığını etkileyebilecek sınırların oldukça altındaydı. Cerrahi ekibin solunum bölgesindeki hava örneklerinde bazı uçucu organik bileşiklerin seviyeleri sınır değerin üzerindeydi. Cerrahi asistanı, steril giyinen hemşire, dolaşıcı hemşire ve yardımcı personelin solunum bölgesindeki benzen seviyeleri normal değerlerin üzerindeydi ve yine yardımcı personelin kloroform seviyesi normal değerin üzerindeydi. **Sonuç:** Ameliyathane çalışanlarının solunum alanındaki cerrahi duman içerisinde bulunan bazı uçucu organik bileşiklerin seviyeleri normal değerin üzerindedir. Ameliyathanelerde cerrahi dumandan korunmaya yönelik protokol oluşturulması ve gerekli önlemlerin alınması önerilmektedir.

Anahtar Kelimeler: Uçucu organik bileşikler; ameliyathaneler; hava kirliliği (kapalı alan); iş sağlığı

Surgical smoke contains gases and particles that emerge as a result of the thermal destruction of tissue by devices used during excision, haemostasis and dissection.[1-3] The heat generated by the use of these devices causes bursting of cell walls, releasing of cellular fluid as vapour and mixing of cell contents into the air.[3] Surgical smoke is visible, and as a result of the breakdown and evaporation of tissue protein and fat, odorous components are released into the environment.[3,4] Moreover, 95% of this odorous component is water, and 5% is cell debris.[3] In addition, 5% of surgical smoke consists of chemicals, blood, tissue particles, viruses and bacteria.[3,5-8]

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The size (aerodynamic diameter) of the particles in surgical smoke causes a direct negative effect on the respiratory system of the surgical team.[5,8-12] Evidence as to whether surgical smoke exposure increases the risk of developing cancer is uncertain.[13-15] The smoke released after using electrosurgical instruments may contain polycyclic aromatic hydrocarbons, volatile organic compounds and carbon monoxide.[13-15] These chemicals can trigger genetic mutations and cancer in the human body. The American Occupational Safety and Health Administration estimate that more than 500,000 health care professionals are exposed to surgical smoke each year.[7]

Studies describing the contents of surgical smoke are limited.[16-25] Therefore, this descriptive study aimed to investigate the effect of surgical smoke on the quality of air in the operating room. This study will contribute to the literature in this field and will provide guidance to future studies related to surgical smoke.

MATERIAL AND METHODS

DESIGN OF THE STUDY

This was a descriptive study.

Population and Sample of the Study

The study sample consisted of four different air samples taken during total mastectomy in the operating room of the general surgery department of a university hospital and 7 healthcare professionals (1-surgeon, 2-surgical resident, 3-anesthesiologist, 4-scrub nurse, 5-circulating nurse, 6-support staff and 7-researcher) that comprised the surgical team.

COLLECTION OF STUDY DATA

This descriptive study's data were collected in August 2018 in the operating room of the department of general surgery of a university hospital.

DATA COLLECTION TOOLS

KITAGAWA AP-20 model (Kitagawa, Japan) device with technical features in ASTM 4490-96 (Determination of Volatile Organic Compounds and Gases by Colorimetric Method) standard was used to obtain air samples. A detector pump, 50-100 mL reservoir for gas and vapour measurements and glass tubes suitable for instantaneous measurement method were used with the device.

BUCK ELITE 5, BUCK LIBRA PLUS and CASELLA APEX 2 model (Zefon International, USA) (ELI50540, ELI50541, ELI50542, ELI50543, ELI50544, 2460983, 4166412, 4166667 and LP051574) devices with TS ISO 16200-1 (Workplace Air Quality-Sampling from Volatile Organic Compounds and Solvent Desorption/Analysis by Gas Chromatography-Part 1: Pump Sampling Method) technical specifications were used in the measurement of volatile organic compounds in the respiratory field.[26]

SURGERY DATA COLLECTION FORM

The researchers created the surgery data collection form based on results of relevant literature.[2,15,21,22,27]

DATA COLLECTION METHOD

In this study, the operating room has a high-efficiency particulate air (HEPA) filter system. Air samples were collected from 4 different parts of the operating room after the use of electrosurgical instruments during surgery. Air samples were taken within the first 30 min in which the electrosurgical instrument was used intensively in the operating room as follows: area where the anaesthesiologist was located (first air sample), area closest to the exit grille of the operating room ventilation (second air sample), area farthest from the source of the smoke in the operating room (third air sample) and area closest to the entrance door of the operating room (fourth air sample) (Figure 1).

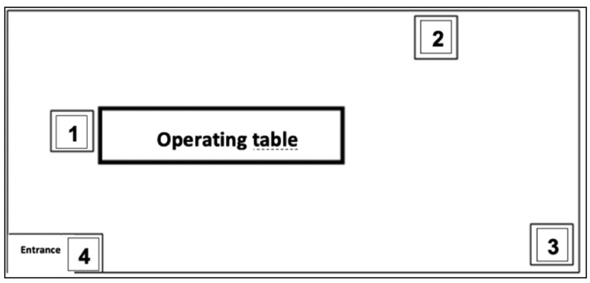

FIGURE 1: Places where air samples were taken.

Before total mastectomy, a device was attached to each surgical team member (surgeon, surgical resident, anaesthesiologist, scrub nurse, circulating nurse, support staff and researcher), and volatile organic compound measurements (pump sampling method) were done in the breathing zone of the surgical team during surgery. The analysis was performed by sampling organic compounds in the air within the breathing zone of the surgical team, and whether the results were within the normal limit/personal exposure measurement was evaluated. This study was performed in line with the principles of the Declaration of Helsinki.

EVALUATION AND ANALYSIS OF DATA

The amount of chemical gases and vapours in the ambient air were measured to determine whether the levels were within the normal limit. Air samples were measured using detector pumps and detector tubes. In this method, the amount of gas in the environment was determined by detector tubes. In these tubes, colour changes can be observed at the moment the gas is drawn, depending on the specific properties of the gas to be measured, with the help of a detector pump capable of drawing a certain amount of gas flow at a certain stroke volume.

Levels of volatile organic compounds in the breathing zone were measured according to the TS ISO 16200-1 Measurement Standards.[26] Air samples were analysed by a private test and analysis laboratory in İzmir.

ETHICAL ASPECT OF STUDY

Permission (date: January 11, 2018; no: E.11195) was obtained from the Clinical Research Ethics Committee of Ege University Faculty of Medicine. Written permission (January 29, 2018-E27595) from the institution where the research was conducted and informed written consent from the study participants was obtained.

RESULTS

AIR SAMPLES COLLECTED DURING THE SURGERY

In the measurement of operating room air samples using a detector pump, the amount of gas was determined when a colour change was observed at the moment gas was drawn, depending on the specific properties of the gas to be measured. Levels of volatile organic compounds could not be detected in the sampled areas, and the levels were well below the limits that could affect human health. Levels of carbon monoxide, carbon dioxide and ozone were within the normal limit. The static pressure was approximately 10 Pascals (Table 1).

The organic compounds in the air from the breathing zone were analysed and the levels of organic compounds were measured. For this sampling method used pump with a device attached to each personnel. Results of measurement determine whether they were within the normal limits. Levels of benzene detected in the breathing zone of the surgical resident, scrub nurse and circulating nurse were above the normal limit. Levels of benzene and chloroform in the breathing zone of the support staff were above the normal limits (Table 2).

DISCUSSION

This study investigated the impact of surgical smoke on the quality of operating room air. Operating room

TABLE 1: Gas and vapour levels in air samples.

Location of measurement	Temperature (°C)	Humidity (%RH)	Pressure (hPa)	Measured gas	Levels (ppm-mg/m^3)
1. Area where the anaesthesiologist is located	25.9	55.6	1009.4	Volatile organic compound Carbon monoxide, carbon dioxide and ozone	Not detected Within normal limits
2. Area closest to the exit grille of the operating room ventilation	25.9	55.6	1009.4	Volatile organic compound Carbon monoxide, carbon dioxide and ozone	Not detected Within normal limits
3. Area farthest from the source of smoke in the operating room	25.9	55.6	1009.4	Volatile organic compound Carbon monoxide, carbon dioxide and ozone	Not detected Within normal limits
4. Area closest to the entrance door of the operating room connected to the corridor	25.9	55.6	1009.4	Volatile organic compound Carbon monoxide, carbon dioxide and ozone	Not detected Within normal limits

TABLE 2: Personal exposure to volatile organic compounds.

Samples	Device location	Temperature (°C)	Humidity (%RH)	Pressure (hPa)	Type of chemical detected	Measurement result (ppm-mg/m3)	Limit value (mg/m3)	Below/above the limit value
Surgeon	Respiratory level	24.9	55.6	1009.4	2-butenol	21.0	450 TWA3	Below
					Acetone	163.3	1210 TWA1	Below
					Ethanol	618.3	1900 TWA3	Below
					Toluene	<11.1*	192 TWA1	Below
Surgical resident	Respiratory level	24.9	55.6	1009.4	2-butenol	20.7	450 TWA3	Below
					Acetone	34.9	1210 TWA1	Below
					Benzene	5.8	3.25 TWA2	Above
					Ethanol	188.2	1900 TWA3	Below
					Toluene	<11.2*	192 TWA1	Below
Anaesthetist	Respiratory level	24.9	55.6	1009.4	2-butenol	31.7	450 TWA3	Below
					Ethanol	<32.1*	1900 TWA3	Below
					Toluene	<11.2*	192 TWA1	Below
Scrub nurse	Respiratory level	24.9	55.6	1009.4	2-butenol	57.1	450 TWA3	Below
					Acetone	<15.5*	1210 TWA1	Below
					Benzene	10.4	3.25 TWA2	Above
					Toluene	<11.2*	192 TWA1	Below
Circulating nurse	Respiratory level	24.9	55.6	1009.4	2-butenol	76.6	450 TWA3	Below
					Acetone	<23.2*	1210 TWA1	Below
					Benzene	6.8	3.25 TWA2	Above
					Ethanol	<32.1*	1900 TWA3	Below
					Toluene	<24.7*	192 TWA1	Below
Support staff	Respiratory level	24.9	55.6	1009.4	2-butenol	159.3	450 TWA3	Below
					Acetone	28.6	1210 TWA1	Below
					Benzene	49.6	3.25 TWA2	Above
					Chloroform	250.8	10 TWA1	Above
					Toluene	56.4	192 TWA1	Below
Researcher	Respiratory level	24.9	55.6	1009.4	Toluene	<11.2*	192 TWA1	Below

*The detected value is below the limit of quantitation (Limit of quantitation: The lowest concentration of a measurand that can be reliably measured by an analytical procedure).

air samples collected from 4 different parts of the operating room during surgery were no volatile organic compounds detected. Levels of carbon monoxide, carbon dioxide and ozone were within the normal limits. These gases levels were below the limits that harm affect for human health. Surgical resident, scrub nurse, circulating nurse and support staff breathing zone air samples level of benzene were above the normal limits. Support staff breathing zone air samples level of chloroform were above the normal limits.

Operating rooms are classified as sterile rooms.[28,29] For use of sterile rooms, ventilation systems can be a laminar flow unit or a HEPA filter system.[29] In a hygienic type air-conditioning system, three layers of filters are used: a primary filter (fibre filter EU-4), a fine filter (bag filter EU-9) as the second layer and an absolute filter (HEPA filter EU-14) as the third layer.[29] The replacement periods of the filters are 1-2 months for the primary filters, 6-8 months for fine filters and 3-5 years for HEPA filters, depending on the external air pollution.[29] In this study, the operating rooms where the study was carried out have HEPA filter systems: primary filters are changed once a month, and particle measurements are performed once a year periodically. Another important parameter of controlling contamination in sterile rooms is static pressure. The pressure should gradually decrease from a very sterile room to a less sterile room.[29] Static pressure between sterile spaces is generally kept at 12 Pascals.[29] In this study, the static pressure was approximately 10 Pascals, and a difference was found because the operating room doors were kept open (Table 1). Romano et al. stated that in air samples taken from operating rooms with different ventilation types, operating rooms with downward ventilation have better results in terms of ventilation and pollutant removal than other types.[2]

The levels of benzene in the air sample obtained from the breathing zone of the surgical resident and scrub nurse were above normal limits. These levels are high because both employees are positioned very close to the source of the surgical smoke, so that they can have a better view of the surgical field and can follow the steps closely during surgery. The level of benzene detected in the breathing zone of the circulating nurse was also above normal limits. This high level was possibly due to the role of the circulating nurse because he/she is also exposed to the surgical smoke in other operating rooms. Moreover, the levels of benzene and chloroform detected in the breathing zone of the support staff were above the normal limits. Benzene was the element with the highest concentration among the volatile organic compounds in the study samples of Choi et al.[18] The findings of our study are similar to those of Choi et al.[18] Contrary to our findings, the World Health Organization's Air Quality Guidelines for Europe reported that if the concentration of benzene in the working environment is 10 ppm and above, there is a positive relationship between benzene exposure level and urinary phenol amount, and the amount of benzene exhaled at a concentration of 10 ppm or less reflects the exposure level.[30] Among other elements, sevoflurane had the highest concentration in the study by Gianella et al. as a result of the analysis of surgical smoke formed during surgery.[20] In the literature about volatile organic compounds with the highest concentration in surgical smoke, Fitzgerald et al., Lin et al., Weston et al., Al Sahaf et al., and Hollmann et al. detected toluene, Zhao et al. detected isobutylene, Näslund Andréasson et al. reported naphthalene and Moot et al. found butadiene 1.3.[16,17,19,21-25] Although the concentration densities of volatile organic compounds in the surgical smoke were different in these studies, the finding that the levels of detected chemicals were above the normal limits was thought-provoking.

CONCLUSION

In this study, volatile organic compounds contained in the surgical smoke sampled from the breathing zone of the surgical team were above the normal limits. Accordingly, since the effect of surgical smoke on the operating room personnel varies depending on the distance of the individuals to the smoke source and their position, similar studies with different sample groups are warranted. It is recommended to establish a protocol for protection from surgical smoke in operating rooms and to take the necessary measures.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

***Idea/Concept:** Burçak Şahin Köze, Meryem Yavuz van Giersbergen, Levent Yeniay; **Design:** Burçak Şahin Köze, Lenevt Yeniay; **Control/Supervision:** Meryem Yavuz van Giersbergen; **Data Collection and/or Processing:** Burçak Şahin Köze, Lenevt Yeniay; **Analysis and/or Interpretation:** Burçak Şahin Köze, Meryem Yavuz van Giersbergen, Levent Yeniay; **Literature Review:** Burçak Şahin Köze; **Writing the Article:** Burçak Şahin Köze; **Critical Review:** Meryem Yavuz van Giersbergen, Levent Yeniay.*

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