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**THE EXAMINATION OF PROBLEMS EXPERIENCED BY NURSES AND
DOCTORS ASSOCIATED WITH EXPOSURE TO SURGICAL SMOKE AND THE
NECESSARY PRECAUTIONS**

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Abstract

Aims and objectives. This study aims to investigate the problems experienced by nurses and doctors as a result of exposure to surgical smoke and the precautions that need to be taken.

Background. Electrosurgery is carried out in almost all operating rooms, and all of those who work in these rooms are exposed to surgical smoke, especially doctors and nurses. A review of the literature reveals that there very few studies have been carried out on surgical smoke, and there are no studies the problems experienced by those working in operating rooms

Design. This descriptive study was conducted between April and June 2015.

Methods. The study was carried out in the operating rooms of Training and Research Hospital with 81 nurses and doctors. Descriptive statistical analyses were performed using the SPSS software package (version 20.00).

Results: The problems experienced by the nurses and doctors as a result of exposure to surgical smoke included: headache (nurses: 48.9%, doctors: 58.3%); watering of the eyes (nurses: 40.0%, doctors: 41.7%); cough (nurses: 48.9%, doctors: 27.8%); sore throat, bad odors absorbed in the hair, and nausea; then drowsiness, dizziness, sneezing and rhinitis.

Regarding the precautions taken to protect themselves from surgical smoke, 91.1% of the nurses and 86.1% of the doctors reported using surgical masks.

Conclusions. It was found that they did not report taking any effective protective measures, and only a few of the nurses reported using special filtration masks. It was observed that the participants widely used surgical masks, which are ineffective in protecting from the effects of surgical smoke.

Relevance to clinical practice: Attention brought to the effects of surgical smoke. Presentation of the harmful effects of surgical smoke reported by doctors and nurses. Identification of the precautions that can be taken against surgical smoke.

Key words: Surgical nursing, Surgery, Occupational exposure, Occupational health

Summary box: What does this paper contribute to the wider global clinical community?

- Contributes to an understanding of the hazards of the surgical smoke for health care workers
- Contributes to enhanced awareness of health care workers about the hazards of the surgical smoke
- Contributes to a discussion of further investigations about the hazards of the surgical smoke

Introduction

Surgical smoke is a plume which is produced by tools that cut or cauterize tissue during surgical operations. These surgical instruments include those used in electrocautery,

lasers, ultrasonic scalpels, high speed drills, burrs and saws. All patients and health care workers are constantly exposed to the hazards of surgical smoke during the perioperative period. Unfortunately, most surgeons, operating room staff and administrators are unaware of the potential health risks of surgical smoke (Fan, Chan, & Chu, 2009). As reported by the Occupational Health and Safety Administration (OSHA) each year, approximately 500,000 workers, including surgeons, nurses, anesthesiologists, and surgical technologists, are exposed to laser or electro-surgical smoke (OSHA, 2015a).

Background

Electrosurgery is carried out in almost all operating rooms, and all of those who work in these rooms are exposed to surgical smoke, especially doctors and nurses. Surgical smoke produced by heat-generating devices consists of 95% water or steam and 5% cellular debris in the form of particulate material (Ulmer, 2008). Studies indicate that surgical smoke also contains viruses, bacteria, tissue material and blood cells as well as harmful chemicals (Sanderson, 2012). Cell components and chemicals that are smaller than 2 μm in size are relocated in the bronchioles and alveoli, which may be harmful to the respiratory system (Okoshi et al., 2015; Ulmer, 2008). It should be noted that different sizes of particles are produced by different surgical instruments. To be more precise, 0.0007-0.42 μm particles are produced by electrocautery, 0.1-0.8 μm particles by laser procedures, and 0.35-6.5 μm particles by ultrasonic scalpels (Fan et al., 2009). Due to the fact that surgical masks generally filter only particles to about 5 μm and larger in size, they do not provide adequate protection for workers and patients (OSHA, 2015a). Moreover, HPV, HIV, tuberculosis, hepatitis B and C viruses can spread into the air within surgical smoke (Brüske-Hohlfeld et al., 2008), and studies indicate that those working in operating rooms can be exposed to

infectious disease due to surgical smoke (Mowbray, Ansell, Warren, Wall, & Torkington, 2013; Ulmer, 2008). Surgical smoke can cause many diseases including acute or chronic respiratory tract infection, hypoxia, eye irritations, watery eyes, coughing, sneezing, headache, nausea, vomiting, fatigue, cardiovascular failure, hepatitis, cancer, in addition to nervous agitation (Dirimeşe, 2013). Surgical smoke also spreads obnoxious smells in the surgical area (In et al., 2015).

Surgical smoke includes chemical as well as biological hazards (Jones, Pierre, Nicoud, Stain, & Melvin, 2006). For example, it contains toxic gases which could have cytotoxic and mutagenic effects (Lewin, Brauer, & Ostad, 2011; OSHA, 2015b). Chemicals that have been observed in the plume generated by laser tissue components include benzene, formaldehyde, acrolein, carbon monoxide and hydrogen cyanide, all of which are known to be harmful to health (Alp, Bijl, Bleichrodt, Hansson, & Voss, 2006). Hill et al. (2012) reported that the effects of exposure to surgical smoke by operating room personnel were similar to those of passive cigarette smoking. The mutagenic and carcinogenic effects of surgical smoke is the same as that of tobacco smoke. As yet, the long-term effects of chronic surgical smoke exposure remain unsubstantiated (Barrett & Garber, 2003; Hill, O'Neill, Powell, & Oliver, 2012); however, appropriate personal protective measures should be provided for operating room employers both because surgical smoke can cause dermatitis, nervous agitation, and to avoid the risk of cancer (Alp et al., 2006).

Ventilation of the operating room is not sufficient to avoid the adverse effects of surgical smoke (Eti Aslan & Öntürk, 2011). For this reason, the use of high filtration masks (Figure 1) and surgical smoke evacuation systems (Figure 2) is recommended (Alp et al., 2006; Eti Aslan & Öntürk, 2011; Fan et al., 2009; In et al., 2015; OSHA, 2015a). Additionally, the surgical team should wear personal protective equipment such as glasses, cap, and gowns (AORN, 2015) Although the use of the smoke evacuation systems are

recommended, these are not used extensively and are not mandatory (Hill et al., 2012; Sanderson, 2012).

Portable smoke evacuation systems, either ULPA (*Ultra Low Particulate Air*) or HEPA (*High Efficiency Particulate Air*), can evacuate smoke particles of nearly 0.12 μm and larger. This filter captures the smaller particle components and protects from adverse effects of surgical smoke. Moreover, the ULPA filter is more effective than HEPA (AORN, 2015; Ulmer, 2008). Recently, portable smoke evacuation systems have been reported to allow continuous ventilation and filtration of the large, small substances, organisms, water vapor, organic and inorganic gases (Alp et al., 2006). The amount of surgical smoke should be calculated prior to surgery, and a smoke evacuation system which is convenient, portable, easy to set up and use, should be utilized during the surgery. The team, including an infection control nurse, a surgeon, an anesthesiologist, a risk manager and an engineer, should decide what kind of smoke evacuation systems can be used for protection against the adverse effects of surgical smoke in the operating room (Özbayır, 2010).

Recent studies indicate that, although the use of wall suction has increased, it is not sufficient alone to protect against surgical smoke (Edwards & Reiman, 2012).

To summarize, it can be said that the hazards of surgical smoke including cytotoxic, genotoxic and mutagenic (Barrett & Garber, 2003). Consequently, operating room staff should recognize the damage of surgical smoke and request that all necessary measures be taken for protection of both operating room staff and patients. At the same time, institutions should take the necessary measures and provide protective equipment for operating room staff. A review of the literature reveals that there very few studies have been carried out on surgical smoke (Hill et al., 2012; In et al., 2015; Yavuz et al., 2010), and there are no studies the problems experienced by those working in operating rooms because of exposure to surgical smoke in particular.

The aim of the current study is to identify the problems related to surgical smoke experienced by doctors and nurses, and the measurements which should be taken.

Methods

The current study is based on the descriptive research design. The study was performed at the Training and Research Hospital in Turkey. The sample of this study also formed the population. The sample consisted of 45 nurses (scrubs and circulating nurses), and 36 doctors (surgeons and anesthesiologists) who participated voluntarily. While 100% of the nurses were reached, it was only possible to reach 35% of the doctors in the population. Nurses and doctors voluntarily completed the “Data Collection Form of Surgical Smoke Risks and Precautions”. This instrument consisted of two sections: the first section included demographic information; the second included information about symptoms experienced after exposure to surgical smoke, the use of surgical smoke evacuation systems, filters on tools producing smoke, and the precautions and protocols implemented by hospitals.

Data analysis was conducted using the SPSS software package (version 20.00). The summarization of the data was enabled by the calculation of frequencies. A Pearson chi-square test of independence was used to test for independence among the main variables. The level of significance was 0.05. Ethical approval for conducting the study was granted by the Ege University Faculty of Nursing Ethics Committee.

Results

The first section of the results presents findings related to the demographic information of the participants (Table 1).

As can be seen in Table 1, 55.6 % of the participants were nurses, and 44.4 % were doctors; 51.9 % of the participants were male and 48.1 % of the participants were female. 40.7 % stated that they had worked for up to five years, 14.8 % from six to 10 years in their profession; and 51.9% stated that they had worked in operating rooms up to five years, and

16.08 % from six to 10 years.

The nurses and doctors' problems associated with exposure to surgical smoke are presented in Table 2: Specifically, 48.9% of the nurses, 58.3% of the doctors reported headaches, 40.0% of the nurses, 41.7% of the doctors watery eyes, 48.9% of the nurses, 27.8% of the doctors coughs, 40.0% of the nurses, 38.9% of the doctors burning throats and 42.2% of the nurses, 36.1% of the doctors bad odors absorbed in the hair, 44.4% of the nurses, 30.6% of the doctors nausea and then successively drowsiness, dizziness, sneeze, rhinitis and other complaints (nervous agitation, respiratory tract infection, weakness, myalgia, dermatitis, conjunctivitis, anemia, cardiovascular disease, nasopharyngeal lesion, abdominal pain, vomiting). The participants who had been exposed to surgical smoke were not diagnosed for HIV, hepatitis B, C or cancer.

A statistically significant difference was found between the nurses and doctors in terms of cough. A statistically significant difference was also found according to gender between nausea and cough. In other words, nurses reported experiencing more coughing problems than doctors, and females reported experiencing more nausea and coughing problems than males.

When the working years of the participants in the operating room are taken into consideration, a statistically substantial difference was found in terms of nausea, rhinitis, dizziness, sneezing, burning throat, abdominal pain, and irritability. Participants who were working in the first five years in operating rooms were found to experience these problems more frequently.

When asked about how they protected themselves from the adverse effects of the surgical smoke, 91.1% of the nurses, 86.1% of the doctors stated that they used surgical masks, 46.7% of the nurses, 11.1% of the doctors glasses, 40.0% of the nurses, 16.7% of the doctors gowns, 13.3% of the nurses, none of the doctors central smoke evacuation system,

4.4% of the nurses, 11.1 of the doctors had used a liquid aspirator, and finally 8.9% of the nurses, none of the doctors informed that they used high filtration masks (Table 3).

None of the participants reported selecting portable surgical smoke evacuation systems or wall suction as protection methods. Moreover, according to the results in Table 3, a statistically significant difference was found between the nurses and doctors in term of protection methods. Specifically, nurses reported using more equipment, such as glasses, gowns, and central smoke evacuation systems.

When examining the level of information about the measures to be taken for surgical smoke in the operating room staff, 69.1 % reported that there were no surgical smoke evacuation systems, 29.6 % stated that they did not know whether or not such a system existed in their operating rooms, and only 1.2 % reported that there was surgical smoke evacuation system. 63 % of the participants stated that surgical protocol had not been made, 37% reported that they had no information about protocols to protect them from the adverse effects of surgical smoke. Moreover, 38.3 % of the participants reported that the reason was a lack of information, 21 % stated that the cost was high, 2.5 % stated that the operating room staff was not sufficient, and 1.2 % also reported that surgical smoke evacuation systems restricted arm and hand coordination and surgical intervention.

Discussion

The increased use of electrocautery and laser treatment in recent years has increased the amount of exposure to surgical smoke (Lewin et al., 2011). In the current study, we found that almost half of the doctors and nurses who participated complained of headaches, watering eyes, coughs, burning throats, bad odors in the hair, and nausea; while a quarter complained of drowsiness, dizziness, and sneezing.

Yavuz et al (2010) found that more than half the nurses who had been exposed to

surgical smoke complained of nausea (63.6%), and approximately half reported coughs, watering eyes, burning throats, and nervous agitation (Yavuz, Kaymakçı, Özşaker, Dirilmeşe, & Okgün, 2010). These findings parallel those of the present study. As reported in Table 2, we found that the nurses exposed to surgical smoke complained most about headaches, coughs, nausea, watering eyes, and burning throats, in order.

After exposure to surgical smoke, nurses experienced significantly more coughs than doctors, and females experienced significantly more coughs and nausea than males ($p \leq 0.05$). Apart from these complaints, it was found that doctors and nurses experienced similar problems (Table 2). This is because nurses work in as close a proximity to the surgical area as do surgeons, and are thus exposed to surgical smoke to the same degree as the surgeons.

Regarding the length of time of exposure to surgical smoke, we found that participants in their first five years of working in operating rooms reported experiencing vomiting, rhinitis, drowsiness, sneezing, burning throat, stomachache and nervous agitation more than those who had been working in such an environment for a longer period. In fact, studies in the literature report that the harmful effects of surgical smoke increase with the period of exposure (Wang et al., 2015). However, in the case of the present study, the fact that approximately half of the participants were in their fifth year of working in operating rooms could account for the increased occurrence of these problems in this period.

Laparoscopic procedures are frequently carried out in operating rooms. In a study aimed at determining the possible dangers of surgical smoke, Choi et al (2014) analyzed the surgical smoke produced by electrocautery during laparoscopic surgery. They found that, unlike open surgery, during laparoscopic and robotic surgery surgical smoke remains in the abdominal cavity until the trocar valve opens, when dense surgical smoke is released into the atmosphere. The volatile organic compounds in the smoke affect those working in the surgical area. Analysis of the smoke collected in the trocar revealed that it contained high risk

carcinogens (ethanol, dichloroethane, benzene, ethylbenzene) (Choi, Kwon, Chung, & Kim, 2014).

Infectious diseases can also be spread via surgical smoke. Studies have reported the presence of *negative staphylococcus*, *corynebacterium*, *neisseira* (Capizzi, Clay, & Battey, 1998); and risks of HIV and HPV (*Human Papilloma Virus*) have also been reported (Lewin et al., 2011). Mowbray et al (2013) did not find any infected cells in the surgical smoke, but they stated that the risks to those working in operating rooms were not known entirely (Mowbray et al., 2013). Although there were no occurrences of HIV or hepatitis in the current study, we did identify occurrences of complaints such as respiratory infections, rhinitis, conjunctivitis, dermatitis, and respiratory problems.

Studies in the literature have shown that surgical masks are most frequently used to protect against the harmful effects of surgical smoke (Yavuz et al., 2010). Similarly, in the present study it was reported that a large majority (88.9%) of doctors and nurses used the surgical mask, which is an ineffective method of protection (Table 3). It is known that surgical masks are not able to protect the wearers from surgical smoke because they cannot hold particles smaller than 5 μm (OSHA, 2015a; Ulmer, 2008). High filtration masks are used by very few nurses. However, some studies have recommended the use of these masks for protection against the harmful effects of surgical smoke (Lewin et al., 2011; Ulmer, 2008).

Regarding the level of knowledge of those working in operating rooms about preventative measures against surgical smoke, Yavuz et al (2010) found that more than half the nurses participating in their study reported there being no protocol regarding protection against surgical smoke, nor any smoke evacuation system. Furthermore, a third of those who worked in operating rooms with a smoke evacuation system reported that they were not used (Yavuz et al., 2010). Most of the participants in the present study also reported that there was no protocol, but some of them reported that they used a central smoke evacuation system.

However, at the time of data collection, the operating rooms had neither a smoke evacuation system, a filter, wall suction, nor a protocol. This finding would suggest a serious lack of information regarding the risks of and necessary precautions against surgical smoke on the part of those working in the operating room.

Reasons for not using smoke evacuation systems have been given as their expense, being noisy, the belief that they disturb the surgeons as they work, and the lack of knowledge about the harmful effects of surgical smoke (Giordano, 1996). The current study also points to this lack of knowledge and the high expense of the systems as the main reason for not using the smoke evacuation systems. However, the price of smoke evacuation systems is around 1000-1500 USD, and one system is sufficient per operating room. To summarize, we found that doctors and nurses experienced problems as a result of exposure to surgical smoke, that they had little information regarding the harmful effects of the smoke, and that they did not take any precautions.

Study limitations

The results from this study must be interpreted in light of some limitations. Our study was restricted to surgical smoke and the precautions that need to be taken at only one university hospital in one region of Turkey. Expanding this study to other hospitals and clinics in other regions of the country warrants consideration.

Relevance to clinical practice

The findings indicate that surgical smoke affects health care workers in the operating room. Unfortunately, they do not take any precautions to protect themselves from the harmful effects of surgical smoke. Future research should now focus on demonstrating the harmful effects of surgical smoke and the content of the smoke should be analyzed. The results of the study should be relevant also all the operating room community, including health care workers and patients.

Conclusion

The current study revealed that doctors and nurses reported experiencing the following complaints due to surgical smoke: headache (nurses: 48.9%, doctors: 58.3%); watering of the eyes (nurses: 40.0%, doctors: 41.7%); cough (nurses: 48.9%, doctors: 27.8%); throat burning cough (nurses: 40.0%, doctors: 38.9%), smell absorbed in the hair (nurses: 42.2%, doctors: 36.1%), nausea (nurses: 44.4%, doctors: 30.6%), drowsiness (nurses: 28.9%, doctors: 24.9%), dizziness (nurses: 28.9%, doctors: 22.2%), and sneezing (nurses: 24.4%, doctors: 22.2%). It was also found that nurses experienced significantly ($p \leq .05$) more coughs than doctors, and females significantly more coughs and nausea.

Although most of the participants were aware of the lack of smoke evacuation systems (69.1%), filtration (63.0%), and a protocol (63.0%), it was found that they did not take any effective precautions, and only a few nurses used special filtration masks. On the other hand, it was observed that they frequently used surgical masks, which are ineffective in preventing the harmful effects of surgical smoke. In other words, it was found that the participants did not know that surgical masks did not protect them from surgical smoke, and that the reason for their not using an effective preventative measure was lack of knowledge (38.3%).

Establishing a safe working environment in operating rooms is of the utmost importance for the health of those working in such environments. For this reason, in order to reduce exposure to surgical smoke to a minimum, filters such as ULPA (*Ultra Low Particulate Air*), and smoke evacuation systems such as HEPA (*High Efficiency Particulate Air*) should be used as recommended by the Association of periOperative Nurses (AORN), protective personal equipment should be worn, procedures and standards determined, and records kept (AORN, 2015). Furthermore, those working in operating rooms should be

informed about surgical smoke, educative programs should be organized, protocols formed, and information provided about any existing protocols and precautions that can be taken.

In order to provide more powerful results, it is recommended that replications of this study be conducted with broader samples in different regions and different countries. In this way, it would be possible to comment on the generalizability of the current results to other institutions and other countries.

Contributions

Study design: AI, GEY, MY; data collection and analysis: AI, GEY; manuscript preparation AI, GEY.

Conflict of interest

No conflict of interest has been declared by the authors.

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Table 1. Defining features of the nurses and physicians in operating room (n:81)

Defining features	Frequency (n)	Percent (%)
Occupational group		
Nurse	45	56.6
Physician	36	44.4
Gender		
Male	42	51.9
Female	39	48.1
Working years ($\bar{x} = 11.75 \pm 9.12$)		
0-5 years	33	40.7
6-10 years	12	14.8
11-15 years	7	8.6
16-20 years	13	16.1
21-25 years	8	9.9
26 and up to 26 years	8	9.9
Working years in operating room ($\bar{x} = 8.56 \pm 8.23$)		
0-5 years	42	51.9
6-10 years	13	16.0
11-15 years	7	8.6
16-20 years	12	14.8
21-25 years	4	4.9
26 and up to 26 years	3	3.8
Total	81	100

Table 2. Frequency and percentages of problems associated with exposure to surgical smoke experienced by nurses and physicians and comparison

Problems	Nurses		Physicians		Chi-square / P (between groups)
	Yes		Yes		
	(n: 45)	(%)	(n: 36)	(%)	
Headache	22	48.9	21	58.3	$X^2=.716$ $p =.397$
Watery eyes	18	40.0	15	41.7	$X^2=.023$ $p =.879$
Cough	22	48.9	10	27.8	$X^2=3.730$ $p=.053$
Throat burning	18	40.0	14	38.9	$X^2=.010$ $P=.919$
The smell of hair	19	42.2	13	36.1	$X^2=.313$ $P=.576$
Nausea	20	44.4	11	30.6	$X^2=1.633$ $P=.201$
Drowsiness	13	28.9	9	24.9	$X^2:.153$ $P=.696$
Dizziness	13	28.9	8	22.2	$X^2:.463$ $P=.496$
Sneeze	11	24.4	8	22.2	$X^2=.055$ $P=.815$
Rhinitis	8	17.8	5	13.9	$X^2=.224$ $P=.636$
Other*	19	42.2	18	50.0	$X^2=:8.872$ $P=.353$

*Other: Irritability, Respiratory tract infection, Weakness, Myalgia, Dermatitis, Conjunctivitis, Anemia, Cardiovascular disease, Nasopharyngeal lesion, Abdominal pain, Vomiting.

Table 3. Frequencies and percentages of methods used for the prevention of surgical smoke (n=81)

Methods	Nurses		Physicians		<i>Chi-square / P</i> (between groups)
	Yes		Yes		
	(n: 45)	(%)	(n: 36)	(%)	
Surgical mask	41	91.1	31	86.1	$\chi^2=.506$ $p=.477$
Glasses	21	46.7	4	11.1	$\chi^2=11.849$ $p=.001$
Gowns	18	40.0	6	16.7	$\chi^2=5.222$ $p=.022$
Central smoke evacuation system	6	13.3	0	0.0	$\chi^2=5.184$ $p=.023$
Liquid aspirator	2	4.4	4	11.1	$\chi^2=.890$ $p=.342$
High filtration masks	4	8.9	0	0.0	$\chi^2=3.366$ $p=.067$

* More than one response provided



Figure 1. High filtration masks (<http://sd-buildout.co.uk/> (Full Support Health and Care, 2015))

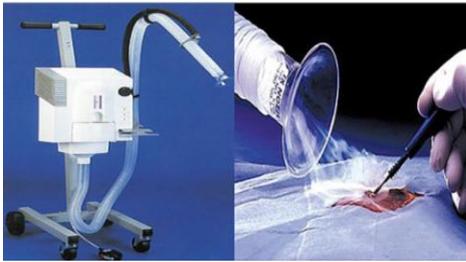


Figure 2. Portable Smoke Evacuation Systems (<http://www.healthandcare.co.uk> (Health and Care, 2015))