Arrival Date: 19.01.2023 | **Published Date:** 30.04.2023 | **Vol:** 8, **Issue:** 2 | **pp:** 354-365 | **Doi Number:** http://doi.org/10.5281/zenodo.7926831

EFFECTS OF EXPOSURE TO SURGICAL SMOKE ON SYMPTOMS IN OPERATING ROOM STAFF: SYSTEMATIC REVIEW AND META-ANALYSIS

AMELİYATHANE ÇALIŞANLARINDA CERRAHİ DUMANA MARUZ KALMANIN SEMPTOMLAR ÜZERİNE ETKİSİ: SİSTEMATİK DERLEME VE META ANALİZ

Zeynep KAPLAN AFACAN[1], Evin KORKMAZ[2], Fadime ÇINAR[3], Fatma ETİ ASLAN[2]

[1] Bahçeşehir University, Department of Nursing, Institute of Graduate Studies, İstanbul, Turkey.
[2] Bahçeşehir University Faculty of Health Sciences, Department of Nursing, İstanbul, Turkey.
[3] İstanbul Nişantaşı University Faculty of Health Sciences, Department of Nursing, İstanbul, Turkey.

ABSTRACT

Objective: Thanks to the rapid development of technology, the number of advanced equipment used in operating rooms is increasing, as in many areas. Although such equipment provides convenience, it also poses some risks for operating room staff and patients. The visible gas released into the environment because of the use of equipment such as electrocautery, laser, ultrasonic scalpel, drill, and saw for the purposes of hemostasis, dissection or excision during surgery is called surgical smoke, which might affect operating room staff negatively.

Material and Method: This systematic review and meta-analysis aims to determine the effect of smoke prevention measures on symptoms in operating room workers exposed to surgical smoke. Descriptive, cross-sectional and prospective cohort studies published between 2010-2021 were evaluated. Eligible studies were selected from the databases of CINAHL, MEDLINE, SCOPUS, Science Direct, Cochrane Library, and Google Scholar on December 21, 2021. Results of 8 studies (6 descriptive, 1 cross-sectional, 1 prospective cohort) were pooled.

Results: The analysis of pooled studies revealed that having knowledge of surgical smoke, presence of an evacuator, frequency of exposure, and the symptoms of headache, nausea, sore throat and burning eyes had a high positive effect on exposure to surgical smoke. Taking precautions against surgical smoke and the symptom of respiratory changes were found to have a negative effect on exposure to surgical smoke.

Conclusion: It was concluded that the incidence of symptoms of headache, nausea, sore throat and burning eyes increased in direct proportion to exposure to surgical smoke, and there was a decrease in respiratory changes because of the exposure. In addition, the exposure decreased as the knowledge level of the operating room workers increased, they took more precautions and they used smoke evacuation devices more, and the incidence of symptoms increased as the frequency of exposure to surgical smoke increased.

Keywords: Electrosurgical Smoke, Occupational Exposure, Occupational Hazard, Precaution, Surgical Smoke.

ÖZET

Amaç: Teknolojinin gelişmesiyle birlikte birçok alanda olduğu gibi ameliyathanelerde de ileri düzey ekipmanların kullanımı artmaktadır. Bu ekipmanlar kullanım açısından kolaylık sağlasa da ameliyathane çalışanları ve hastalar açısından bazı riskleri de barındırır. Cerrahi duman, elektrokoter, lazer, ultrasonik neşter, matkap, testere gibi ekipmanların ameliyat sırasında hemostaz, diseksiyon ya da eksizyon amaçlı kullanılması sonucu ortama salınan görünür özellikteki gazdır. Ameliyathane çalışanları bu durumdan olumsuz etkilenebilirler.

Gereç ve Yöntem: Bu sistematik derleme ve meta analizde, cerrahi dumana maruz kalan ameliyathane çalışanlarında dumandan korunmaya yönelik önlemlerin semptomlar üzerindeki etkisi belirlenmesi amaçlandı. 2010-2021 yılları arasında yayınlanan tanımlayıcı, kesitsel ve prospektif kohort çalışmalar değerlendirildi. 21 Aralık 2021 tarihinde CINAHL, MEDLINE, SCOPUS, Science Direct, Cochrane Library, Google Scholar veri tabanlarından uygun çalışmalar seçildi. Toplam 8 çalışmanın sonuçları (6 tanımlayıcı, 1 kesitsel, 1 prospektif kohort) birleştirildi.

Bulgular: Birleştirilmiş çalışmaların analizinde; cerrahi duman hakkında bilgi sahibi olma, tahliye cihazının varlığı, maruz kalma sıklığı ile baş ağrısı, bulantı, boğazda yanma, gözlerde yanma semptomlarının cerrahi dumana maruz kalma üzerinde pozitif yönde yüksek etki büyüklüğüne sahip olduğu bulundu. Cerrahi dumana yönelik önlem alma ve solunum değişiklikleri semptomu ise cerrahi dumana maruz kalma üzerinde negatif yönde etki büyüklüğüne sahip olduğu bulundu.

Sonuç: Cerrahi duman maruziyetine bağlı ameliyathane çalışanlarında baş ağrısı, bulantı, boğazda yanma ve gözlerde yanma bulguları maruziyetle doğru orantılı olarak arttığı, solunum değişikliklerinde ise azalma olduğu sonucu elde edildi. Ameliyathane çalışanlarının bilgi düzeyleri, önlem alma yöntemleri ve duman tahliye cihazları kullanımı arttıkça maruziyetin azaldığı, dumana maruz kalma sıklığı arttıkça semptomların da arttığı sonuçlarına ulaşıldı.

Anahtar Kelimeler: Cerrahi Duman, Elektrocerrahi Dumanı, Mesleki Maruziyet, Mesleki Tehlike, Önlem.

Sorumlu Yazar / Corresponding Author: Zeynep KAPLAN AFACAN, Msc., Bahçeşehir University, Department of Nursing, Institute of Graduate Studies, İstanbul, Turkey. **E-mail:** zeynepkaplan.f@gmail.com

Bu makaleye atıf yapmak için / Cite this article: Afacan Kaplan Z., Korkmaz E., Çınar F., Eti Aslan F. (2023). Effects of Exposure to Surgical Smoke on Symptoms in Operating Room Staff: Systematic Review and Meta-Analysis. *Gevher Nesibe Journal of Medical & Health Sciences,* 8(2), 354-365. http://doi.org/10.5281/zenodo.7926831

INTRODUCTION

Thanks to the rapid development of technology, the number of advanced equipment used in operating rooms is increasing, as in many areas. Although such equipment provides convenience, it also poses some risks for operating room staff and patients (Olgun, 2020; Tseng et al., 2014). The visible gas released into the environment because of the use of equipment such as electrocautery, laser, ultrasonic scalpel, drill, and saw for the purposes of hemostasis, dissection or excision during surgery is called surgical smoke (SS) (İlçe et al., 2017; Mowbray et al., 2013). SS occurs due to the high temperature that the cell is exposed to during cautery application, which is used for hemostasis of tissue and blood vessels, thus causing the intracellular fluid to boil, the protein and organic substances to burn, and the fat and protein in the surrounding tissues to break down (Olgun, 2020). Of the visible and odorous SS, 95% is composed of water and 5% of particles such as dead cell debris, fragments of blood, viruses, and bacteria (İlçe et al., 2017). In addition, polycyclic aromatic hydrocarbons (PAHs) such as naphthalene, phenanthrene, benzene, formaldehyde and hydrogen cyanide are also found in SS (Alver et al., 2012; Benson et al., 2019; Claudio et al., 2017; Tseng et al., 2014; Van Gestel et al., 2020). These particles and PAHs are potentially dangerous to human health due to their toxic and carcinogenic characteristics. Aerosolized SS increases the risk of transmission of pathogens such as Human Immunodeficiency Virus (HIV), Human Papillomavirus (HPV) and Hepatitis B to patients and staff (Keeley and Smalley, 2022).

The most common symptoms observed in operating room staff due to inhalation of SS were reported to be headache (17.9%), nasal congestion (15.4%), and eye irritation (15.4%), respectively (Stanganelli et al., 2019). Another study examining the symptoms observed in nurses found that headache (26.1%), eye irritation (23.9%), and oral or nasal mucosal irritation (17.4%) were the most common ones (Saito et al., 2019). It was reported that respiratory symptoms related to SS exposure in physicians trained in the operating room were foreign body sensation in the throat with 58%, pharyngeal soreness with 22%, and nausea with 4% (Navarro-Meza et al., 2013), while the most common symptoms due to SS exposure in nurses working in the operating rooms of different hospitals were headache with 61.9%, lachrymation with 54.3% and sneezing with 44.8% (Usta et al., 2019). The most common symptoms of SS reported in the literature are headache (71.8%), nausea (63.4%), cough (57.7%) (Alcan et al., 2017), throat irritation (56.6%) (Ünver et al., 2016), lachrymation (41.7%) (İlçe et al., 2017). In another study examining 672 operating room workers with similar results, respiratory changes (57.3%) were reported in addition to these symptoms (Van Giersbergen et al., 2019). The cohort study Xie et al. conducted with 75.011 nurses in 2021 reported that the risk of developing Chronic Obstructive Pulmonery Disease (COPD) was 69% higher in nurses who worked in the operating room for 15 years or longer compared to those who did not work in the operating room (Xie et al., 2021). The Occupational Safety and Health Administration (OSHA) of the US Department of Labor announced that more than half a million operating room workers, including surgeons, nurses, anesthetists, and surgical technologists, are exposed to SS each year (OSHA, 2022). High filtration masks (N95, N99, N100 etc.) and smoke evacuation systems (general ventilation, central smoke extraction systems, wall-mounted ventilator, evacuation device, etc.) are among the measures that can be taken to prevent exposure in operating room workers (Van Giersbergen and Şahin Köze, 2022). In their study in which they examined the bacterial and particulate filtration performance of surgical masks and user compliance, Oberg and Brosseau (2008) reported that none of the masks included in the study had satisfactory filtration performance and did not fit the participants' faces to provide sufficient respiratory protection (Oberg and Brosseau, 2008). In their systematic review and meta-analysis examining the effects of surgical masks and N95 masks in the prevention of acute respiratory infections, Smith et al. (2016) found that there was not enough data showing that N95 masks are superior to surgical masks (Smith et al., 2016). In a randomized controlled study examining the effects of a smoke evacuation system to investigate the amount of smoke reaching the surgeon's mask in different types of surgery, the content of the smoke on the surgeon's mask was analyzed, and it was reported that fewer particles were measured in the smoke content in the surgeries in which an evacuation system was switched on compared to those in which it was not (Pillinger et al., 2003). On the other hand, Spearman et al. (2007) reported in their study with 169 surgeons and nurses working in the operating room that only 3% of the surgeons used an evacuation device, 26% thought that adequate precautions were taken, and that the nurses were not authorized to use evacuation equipment because it was at the discretion of the surgeon (Spearman et al., 2007). Ball (2010) examined the compliance of 777 perioperative nurses with smoke evacuation procedures and reported that it was affected negatively due to the complexity of the procedures (Ball, 2010). Although

the risks and biological effects of SS exposure have been proven, the regulations made to prevent such exposure are insufficient (Canicoba and Brito Poveda, 2021).

The literature indicates that studies have been carried out on the symptoms in the operating room staff exposed to SS (Alcan et al., 2017; İlçe et al., 2017; Navarro-Meza et al., 2013; Saito et al., 2019; Stanganelli et al., 2019; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019; Xie et al., 2021), SS analysis (Benson et al., 2019; Claudio et al., 2017; Van Gestel et al., 2020), and measures taken to prevent SS (Hahn et al., 2017, Liu et al., 2020).

Research questions

This study aims to determine the effect size of the operating room staff's knowledge about SS and the use of a smoke evacuator on the symptoms.

MATERIALS AND METHODS

Literature Review

Literature review was performed using the databases of CINAHL, MEDLINE, SCOPUS, Science Direct, Cochrane Library, and Google Scholar. The following keywords were used for the review: "surgical smoke" OR "smoke surgical" OR "surgical smoke plume" OR "electrosurgery smoke" OR "electrocautery smoke" AND "surgery". MeSH (Medical Subject Headings) thesaurus was used while creating the keywords. The studies published in national and international journals in 2010 and later, regardless of whether the full text was available and the language of publication, were reviewed. Studies in Turkish, English and Spanish are included in the publication language. The literature review was carried out on December 21, 2021.

Selection of Studies

The inclusion criteria were that the study was related to human health, a research article with full text published, and conducted in 2010 and later. The exclusion criteria were that the study was COVID-19 pandemic related, its full text was not available, and it was related to smoke analysis.

Assessment of Methodological Quality of Studies

A checklist the Joanna Briggs Institute (JBI) developed for systematic reviews and research syntheses was used for the quality assessment of the studies (JBI, nd). This checklist consists of eleven items that are marked as "yes, no, unclear, not applicable". The assessment results for each included study are presented in Table 1. Two of the researchers (ZKA, EK) carried out the quality assessment process. The questions answered differently were reviewed and discussed, and a common decision was reached.

Table 1. Quality assessment scores

Researcher(s) and year	Type of study	Quality score
Stanganelli et al.[10], 2019	Prospective cohort study	Yes: 11/11 No: 0/0
Saito AC et al.[11], 2019	Cross-sectional study	Yes: 9/1 Unclear: 2/11
Usta et al.[13], 2019	Descriptive study	Yes: 11/11 No: 0/0
Okgün Alcan et al.[14], 2017	Descriptive study	Yes: 9/11 Unclear: 2/11
Aydın et al.[29], 2021	Descriptive study	Yes: 9/11 Unclear: 2/11
Van Giersbergen et al.[16], 2019	Descriptive study	Yes: 8/11 No: 1/11 Unclear: 2/11
Ünver et al.[15], 2016	Descriptive study	Yes: 9/11 Unclear: 2/11
İlçe et al.[4], 2016	Descriptive study	Yes: 9/11 Unclear: 2/11

Extraction of Data

The form the researchers developed was used as the data extraction form. Data such as the name of the study, publication year and language, place and type of study, sample size, and symptoms observed in operating room staff were obtained using this form. Two of the researchers (ZKA, EK) performed the data extraction process independently. In case the extracted data turned out to be different, the studies were re-examined and correct data were obtained.

Statistical Analysis

In this systematic review, the data obtained from the quantitative studies (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Saito et al., 2019; Stanganelli et al., 2019; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019) were pooled by performing a meta-analysis (pooled estimates). The meta-analysis was performed using Comprehensive Meta-Analysis Version 3 (Comprehensive meta-analysis, nd). Heterogeneity between the studies was assessed using Cochran's Q and Higgins I^2 tests, and an I^2 greater than 50% was considered to indicate statistically significant heterogeneity. If I^2 was 50% or more, random effects results; if it was less than 50%, fixed effects results were considered. The 95% confidence interval (CI) and Estimated Ratios (ORs) were calculated for each outcome variable (DerSimonian and Laird, 1986). An OR equal to 1 indicates that there is no relationship between the variables, and that higher than 1 indicates that the risk ratio has an effect (Dinçer, 2014). The studies included in the meta-analysis were grouped into five main categories. Considering the heterogeneity test according to these categories, four of them were analyzed using random effects and one of them using fixed effects results (Table 2).

Table 2: Heterogeneity test results by parameters

Heterogeneity test	Q value	df (Q) value	p value	I^2
Having knowledge of surgical smoke	126.673	3	0.000	97.632
Taking precautions against surgical smoke	305.176	5	0.000	98.362
Symptoms related to surgical smoke	21.183	7	0.004	66.954
Presence of surgical smoke evacuation device	5.786	5	0.328	13.582
Frequency of exposure to surgical smoke	18.991	7	0.008	63.140

RESULTS

Results of the Review

Initially, 1308 studies were reached. Two of the researchers (ZKA, EK) independently analyzed the titles and abstracts of these studies first. Opinion of the other researcher (FÇ) was sought in cases where there was inconvenience or uncertainty in the selection. As a result of the review, the remaining 167 studies with full text were analyzed. Of those whose full texts were reviewed, 159 were excluded because 58 of them were duplications, 42 were not relevant, and 59 did not meet the inclusion criteria. The remaining eight studies were included in this study. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram was used in the process of reducing the 1308 studies to eight and reporting them (Figure 1). Cohort, cross-sectional, and descriptive studies were included in the study.

Characteristics of Studies and Participants

Six of the studies included in the systematic review and meta-analysis were descriptive (75%), one was cross-sectional (12.5%) and one was prospective cohort study (12.5%). The sample size in the studies ranged from 39 to 672. The studies included in the analysis were published between 2013 and 2021 and their data were collected after 2012 (Table 1).

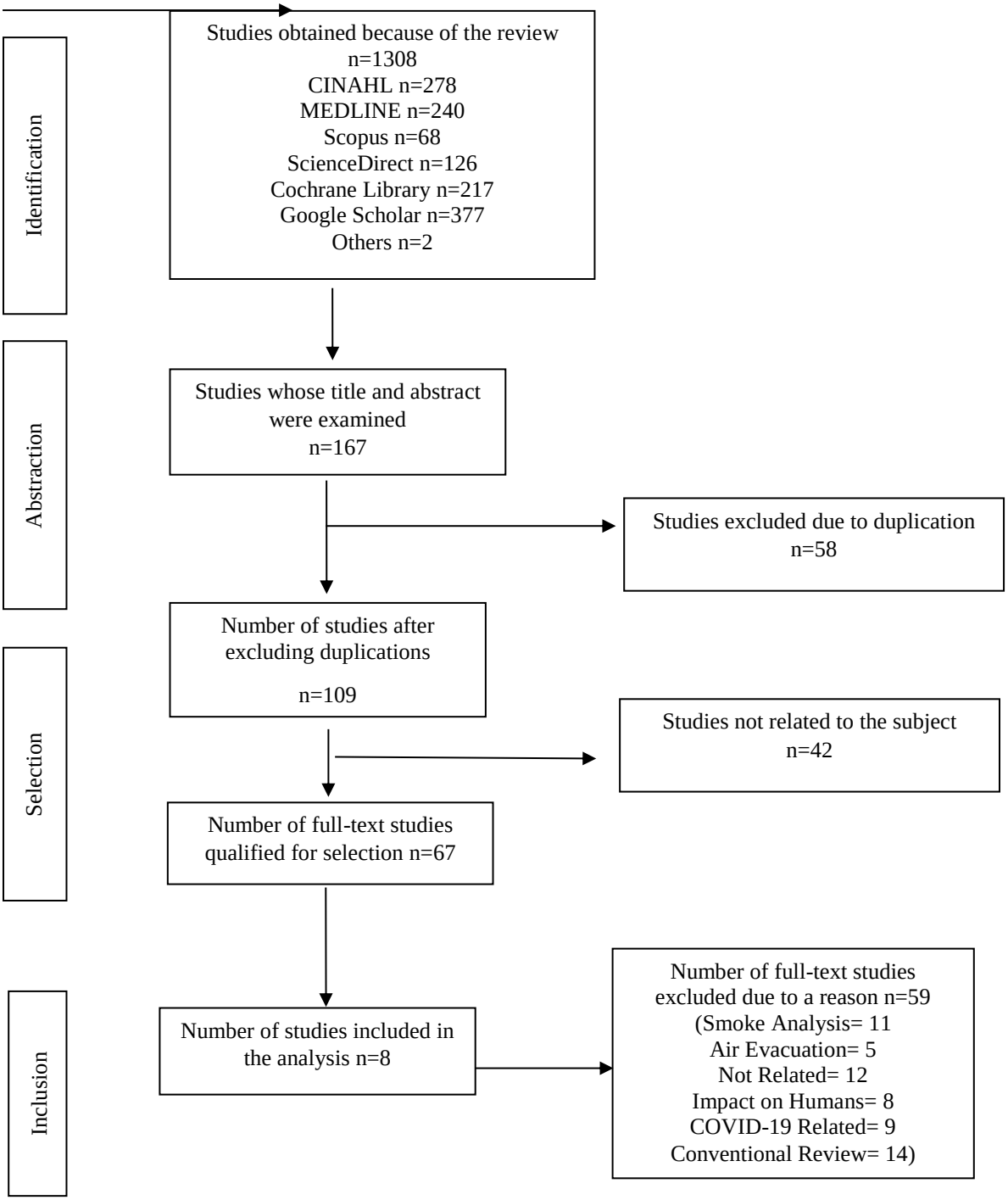


Figure 1: PRISMA flow diagram

Quality Assessment Results

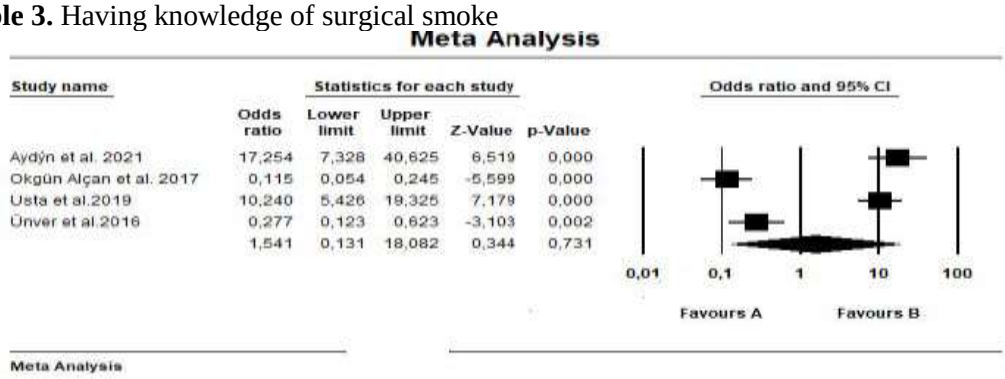
The studies included in the systematic review and meta-analysis were assessed independently by two researchers (ZKA, EK). The kappa values of the quality scores obtained because of the assessment are interpreted as follows: <0 shows worse agreement than chance, 0.01-0.20 slight, 0.21-0.40 fair, 0.41-0.60 moderate, 0.61-0.80 substantial and 0.81-1.00 near perfect agreement; or a kappa of 0.75 and greater shows excellent agreement, 0.40-0.75 fair to good and that below 0.40 poor agreement (Kılıç, 2015). The kappa value of this study is 0.61, which indicates that there is substantial agreement between the coders.

Among the studies included in this study, six descriptive studies received the answer "Yes" to 11 items from the 11-item quality assessment tool, one cross-sectional study to 9 items, and one cohort study to 11 items (Table 1).

Meta-analysis Results

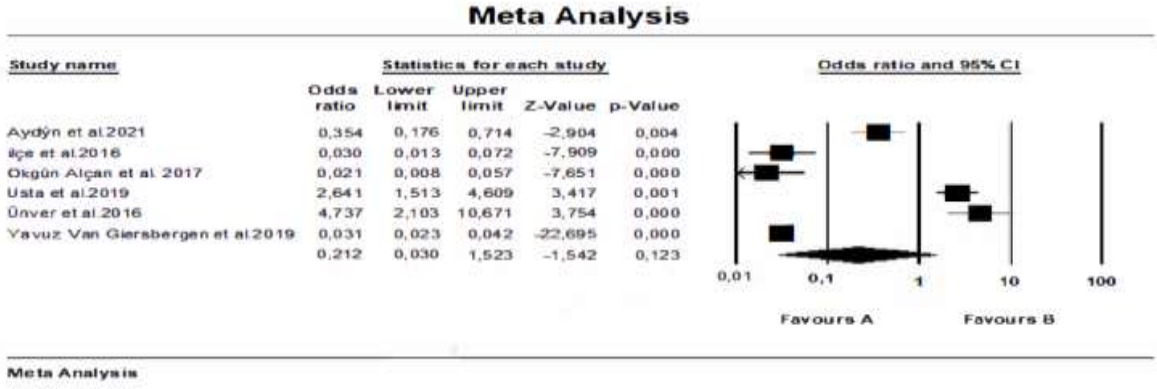
In the studies included in this systematic review and meta-analysis, the problems related to SS exposure were identified in five categories.

Table 3. Having knowledge of surgical smoke



Four of these studies reported that the operating room workers had knowledge about SS (Alcan et al., 2017; Aydın et al., 2021; Usta et al., 2019; Ünver et al., 2016). When the effect of knowing about SS on exposure to SS was evaluated, it was found that the studies were significant alone, but not statistically significant compared to the pooled results (p=0.731). In addition, it was revealed that knowing about SS had a high positive effect on SS exposure (Table 3) (OR=1.541; 95% CI: 0.131-18.082; z=0.344; p=0.731; I2 =97.632%)

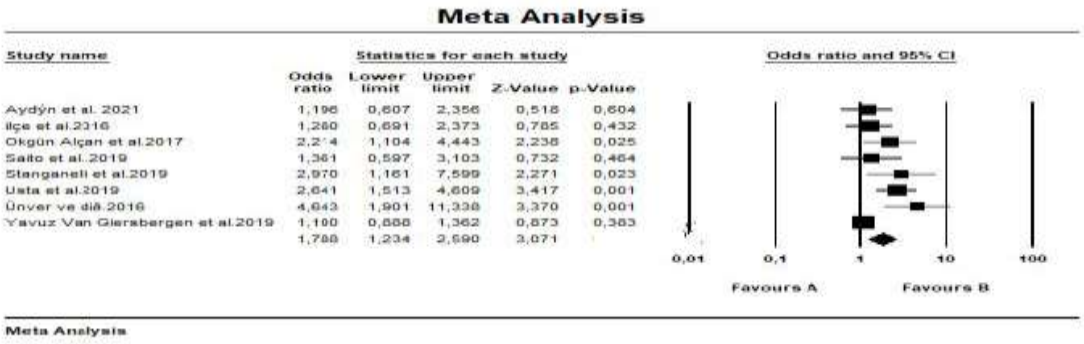
Table 4. Taking precautions against surgical smoke



Considering the results of the six studies included in the category of taking precautions against SS (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019), it was found that its effect on SS exposure was significant alone, but not statistically significant compared to the pooled results (p=0.123). It was also found that taking precautions against SS had a negative effect on SS exposure (Table 4) (OR=0.212; 95% CI: 0.030-1.523; z=-1.542; p=0.123; I^2 =98.362%).

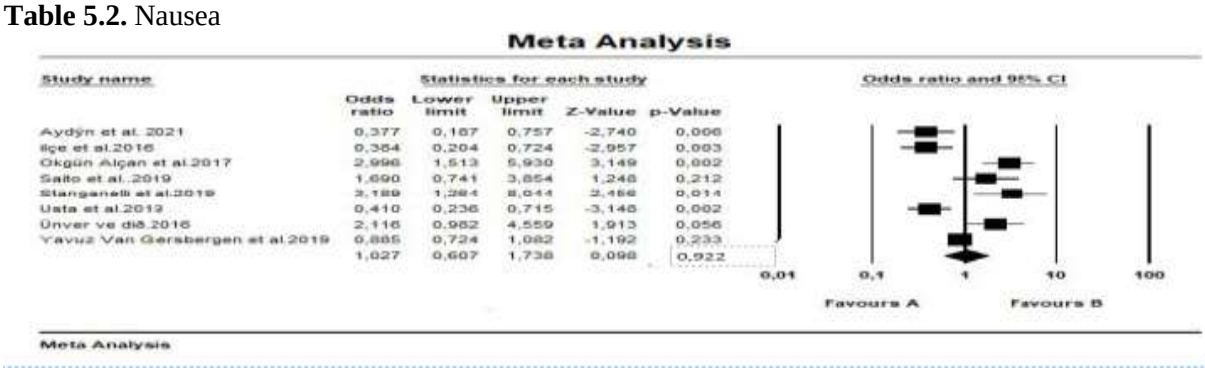
Symptoms related to surgical smoke

Table 5.1. Headache



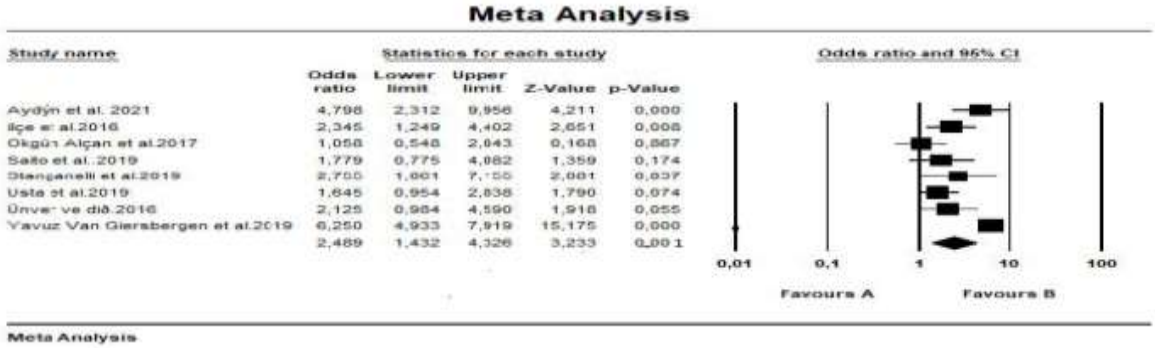
The effect of SS exposure on headache was observed in eight of the studies included in the meta-analysis (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Saito et al., 2019; Stanganelli et al., 2019; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019). The pooled results of the studies revealed that SS had a high positive effect on headache (Table 5.1) (OR=1.788; 95% CI: 1.234-2.59; z=3.071; I^2 =66.954%).

Table 5.2. Nausea



The effect of SS exposure on nausea was examined in all eight studies (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Saito et al., 2019; Stanganelli et al., 2019; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019), included in the meta-analysis. According to the pooled results of the study, it was not statistically significant (p=0.922). It was found that SS exposure had a positive effect on nausea (Table 5.2) (OR= 1.027; 95% CI: 0.607-1.738; z=0.098; p=0.922; I^2 =66.954%).

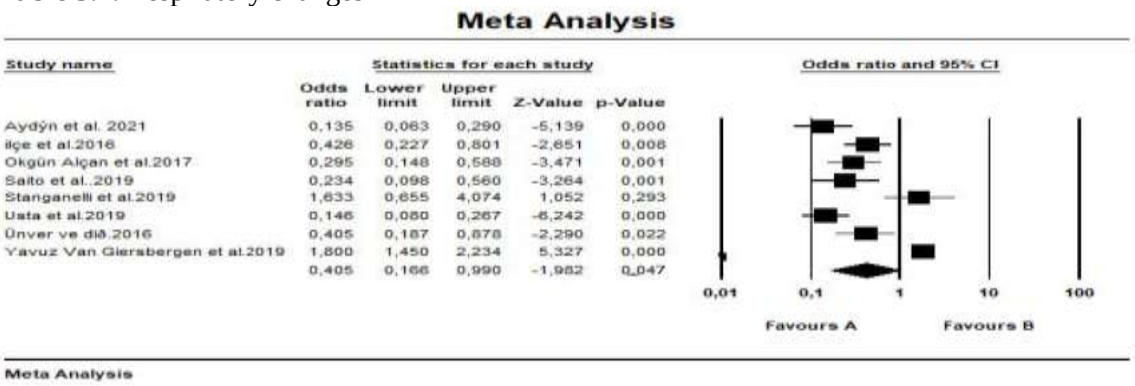
Table 5.3. Sore Throat



When the eight studies (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Saito et al., 2019; Stanganelli et al., 2019; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019) reporting the symptoms of sore throat due to SS exposure in operating room workers were examined, SS exposure

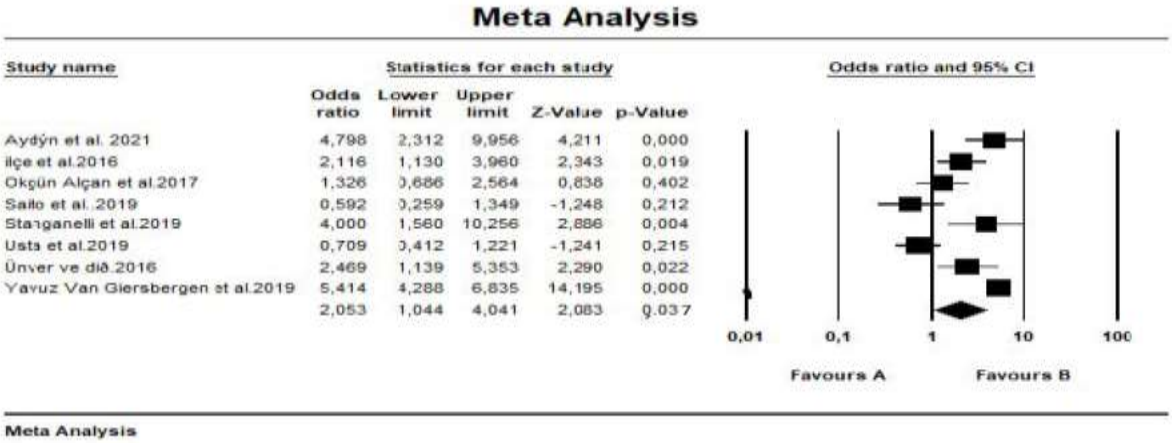
was statistically significant compared to the pooled results (p=0.001) and had a high positive effect (Table 5.3) (OR=2.489; 95% CI: 1.432-4.326; z=3.233; p=0.001; I^2=66.954%).

Table 5.4. Respiratory changes



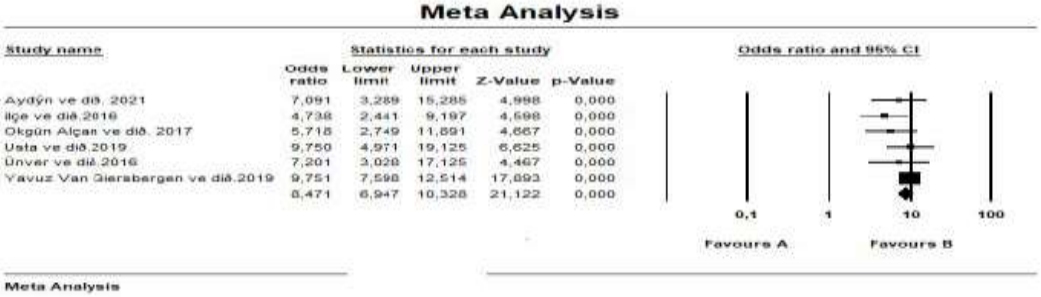
It was observed in eight of the studies included in the meta-analysis (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Saito et al., 2019; Stanganelli et al., 2019; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019) that operating room workers exposed to SS suffered from respiratory changes, and these studies were statistically significant (p=0.047) and had a negative effect size (Table 5.4) (OR=0.405; 95% CI: 0.166-0.99; z=-1.982; p=0.047; I^2=66.954%).

Table 5.5. Burning eyes



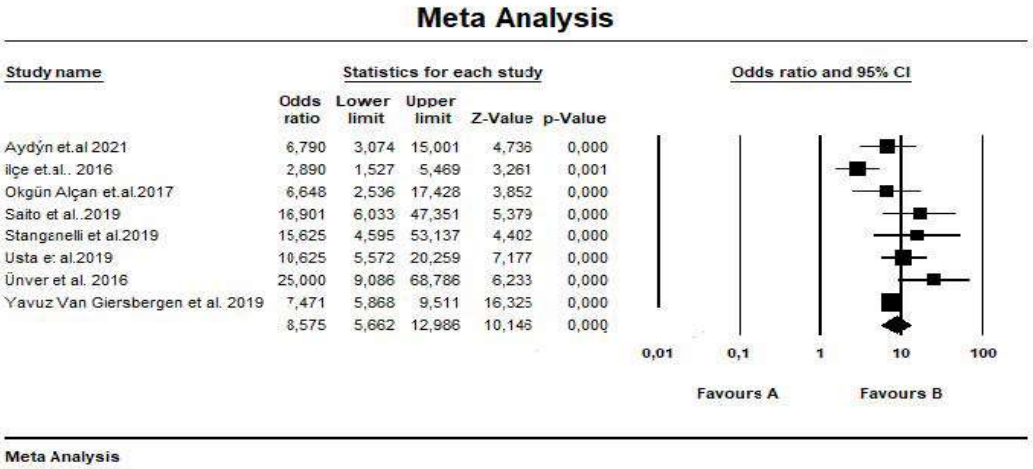
The effect of SS exposure on the symptom of burning eyes was examined in eight of the studies included in the meta-analysis (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Saito et al., 2019; Stanganelli et al., 2019; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019). According to the pooled results of the studies, it was found to be statistically significant (p=0.037) and to have a high positive effect size (Table 5.5) (OR=2.053; 95% CI: 1.044-4.041; z=2.083; p=0.037; I^2 =66.954%).

Table 6. Presence of surgical smoke evacuation device



The effect of the presence of an SS evacuator on symptom occurrence was examined in six of the studies (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019) included in the meta-analysis. According to the pooled results of the studies, it was found to be statistically significant (p=0.000) and to have a high positive effect size (Table 6) (OR=8.471; 95% CI: 6.947-10.328; z=21.122; p=0.000; I^2=13.582%).

Table 7. Frequency of exposure to surgical smoke



According to the pooled results of the eight studies (Alcan et al., 2017; Aydın et al., 2021; İlçe et al., 2017; Saito et al., 2019; Stanganelli et al., 2019; Usta et al., 2019; Ünver et al., 2016; Van Giersbergen et al., 2019) examining the effect of the frequency of operating room workers' exposure to SS on symptoms, it was found to be statistically significant (p=0.000) and to have a high positive effect size (Table 7) (OR=8.575; 95% CI: 5,662-12,986; z=10.146; p=0.000; I^2=63.140%).

DISCUSSION

This study was conducted as a systematic review and meta-analysis in order to investigate the symptoms observed due to SS exposure, the conditions affecting SS exposure and the precautions taken to prevent SS exposure in healthcare personnel working in the operating room. Since, to the best of our knowledge, there is no meta-analysis study on this subject in the literature, the discussion was made using similar systematic reviews.

When the effect of knowing about SS on SS exposure was evaluated in the study, it was found that while the studies were significant alone, they were not statistically significant compared to the pooled results (p=0.731), and having knowledge of SS had a high positive effect on SS exposure (OR=1.541). Lindsey et al. (2015) reported in their systematic review study that having knowledge of SS positively affects compliance with the procedures related to SS prevention (Lindsey et al., 2015). Another study reported that 68% of the participants working in the operating room and exposed to SS were not aware of the dangers and protective measures against SS or did not have any available procedures, and if the operating room nurses were trained about SS, their compliance with the procedures of smoke protection and evacuation increased (Stanley, 2019). It can be argued based on these results that operating room staff do not have enough knowledge about SS, and as the level of knowledge increases, more precautions are taken against SS exposure.

It was observed that taking precautions to avoid SS had a negative effect on SS exposure (OR=0.212). The study Lindsey et al. (2015) conducted with 169 operating room workers found that physicians who received medical training in the field of surgery (70%) were more likely to use smoke evacuation equipment to take precautions compared to specialist physicians (43%) (Lindsey et al., 2015). A study included in another systematic review reported that only 3% of surgeons used a smoke evacuator as a precaution. Seventy-two percent of the staff participating in the study reported that the precautions taken to protect against potential harms of SS were insufficient (Bree et al., 2017). Assessing the efficiency of mask filters, a meta-analysis study reported that standard surgical masks provide 97% and N95 masks with HEPA (high-efficiency particulate air) filters 99.99% protection against smoke

particles with an average size of 1 µm (micrometer) (Georgesen and Lipner, 2018). This study revealed that the SS exposure of the operating room workers decreased as they took precautions against SS. Based on these results, it can be argued that taking precautions with appropriate equipment reduces SS exposure.

According to the pooled results of the studies, SS exposure was found to have a high positive effect on headache (OR=1.788). In the systematic review Canicoba et al. carried out, headache was reported in four (50%) of the eight studies (Calicoba and Brito Poveda, 2021). The study Asdornwised et al. conducted with 377 perioperative nurses found that 79% of them experienced headache (Asdornwised et al., 2018).

SS exposure was found to have a positive effect on nausea (OR=1.027) in these studies. Canicoba et al. reported that nausea was observed in operating room workers in three (37.5%) of the eight studies (Calicoba and Brito Poveda, 2021). A study reported that 63% of nurses had nausea problems (Asdornwised et al., 2018).

This study found that SS exposure had a high positive effect on sore throat in operating room workers (OR=2.489). All eight (100%) studies included in the systematic review examining symptoms associated with SS exposure in operating room workers reported sore throat, throat irritation, or throat ache (Calicoba and Brito Poveda, 2021). A study showed that 74% of nurses suffered from sore throat (Asdornwised et al., 2018).

The results of this study indicated that SS had a negative effect on symptoms of respiratory changes (OR=0.405). The Health and Safety Executive (HSE) in the United Kingdom published a report on the harmful effects of SS exposure in 2012, in which a study conducted with 777 nurses found that the incidence of respiratory-related problems in perioperative nurses was twice that of general nurses (Beswick and Evans, 2021). In addition, higher rates of allergy (18.4% compared to 24.2%), asthma (6.4% compared to 10.9%), and bronchitis (4.5% compared to 9%) were reported in nurses (Lindsey et al., 2015; Beswick and Evans, 2021). Respiratory symptoms (coughing, sneezing, chronic bronchitis, asthma, etc.) were reported in all (100%) of the studies included in the systematic review of Canicoba et al. (Calicoba and Brito Poveda, 2021). A study found that 73% of nurses had coughing/sneezing problems and these symptoms were observed at their highest intensity (Asdornwised et al., 2018).

The results of this study revealed that SS exposure had a high positive effect on burning eyes (OR=2.053). Twenty-five percent of the studies included in the systematic review by Canicoba et al. reported eye irritation, lachrymation or burning eyes (Calicoba and Brito Poveda, 2021). A study showed that 70% of nurses had eye irritation problems (Asdornwised et al., 2018).

According to the results of this study, as SS exposure increased in operating room workers, the symptoms of headache, nausea, sore throat and burning eyes increased, too. As reported in the literature and in this study, it is thought that an increase in operating room workers' exposure to SS results in an increase in the occurrence of negative symptoms. On the other hand, the reason for the decrease in respiratory changes (cough, sneezing, bronchitis, etc.) as SS exposure increased might be that those working in the operating room used surgical masks or high filter masks.

The use of a smoke evacuation device was found to have a high positive effect on SS exposure (OR=8.471). In their systematic review, Stanley et al. reported that 51% of surgeons used smoke evacuation devices, and 73% of them preferred to use these devices because they improve the field of view, 57% because they provide safety, and 16% because they prevent the smell caused by smoke (Stanley, 2019). Edwards et al. investigated the SS control measures and the use of smoke evacuation systems of 623 operating room workers and reported that the use of these devices varied depending on the surgeon's perception of danger or the amount of SS produced (Edwards and Reiman, 2008). Lindsey et al. found that the most frequently reported reason for not using smoke evacuation systems was the surgeon's unwillingness or refusal to use them (Lindsey et al., 2015). The literature and the results of this study indicate that the use of a smoke evacuation device, which is one of the measures taken to prevent the harmful effects of SS, will significantly reduce SS exposure.

The present study also revealed that the frequency of SS exposure had a high positive effect on the symptoms (OR=8.575). Fow-Lewis et al., in their systematic review, examined the incidence of HPV in operating room workers exposed to SS, and reported more skin lesions in those exposed to SS for more than five years (77%) compared to those exposed for five years or less (23%) (Fox-Lewis et al., 2020). The HSE report Beswick et al. prepared showed that 97% of 111 surgeons and residents were always or frequently exposed to SS (Beswick and Evans, 2012). When the findings of this study and the

literature are examined, it is observed that the incidence of symptoms increases as the frequency of SS exposure increases. The reason is the thought that as the frequency of exposure to SS, which has potentially negative effects on human health, increases, the symptoms will inevitably increase, too.

CONCLUSION

This study concluded that the symptoms of headache, nausea, sore throat and burning eyes due to SS exposure increased in direct proportion to the exposure in operating room workers, and there was a decrease in respiratory changes. It was also concluded that as the knowledge level of operating room staff increased, smoke evacuation devices were used more, and more precautions were taken, SS exposure decreased, and that the symptoms increased as the frequency of exposure to SS increased.

It is recommended to develop standard procedures for SS in the operating room and to provide more staff training in this regard, to use smoke evacuation devices effectively, to prefer masks with high filtration, and to increase the number of staff in order to reduce the frequency of exposure.

Author Contributions

Plan, design: ZKA, EK, FÇ, FEA; **Material, methods and data collection**: ZKA, EK, FÇ; **Data analysis and comments:** ZKA, EK, FÇ, FEA; **Writing and corrections:** ZKA, EK, FÇ, FEA.

Conflict of Interest

Authors declare that there is no conflict of interest.

Funding

This study was not financially supported.

REFERENCES

Alcan, AO, Van Giersbergen, MY, Tanıl, V, Dinçarslan, G, Hepçivici, Z, Kurcan, Ç, Dere, T. (2017). Examination of surgical smoke risks and protective measures in a university hospital. Journal of Ege University Faculty of Nursing, 33(2), 27-35.

Alver, E, Demirci, A, Özcimder, M. (2012). Polycyclic aromatic hydrocarbons and their effects on health. Mehmet Akif Ersoy University Journal of Science Institute 3(1), 45-52.

Asdornwised, U, Pipatkulchai, D, Damnin, S, Chinswangwatanakul, V, Boonsripitayanon, M, Tonklai, S. (2018). Recommended practices for the management of surgical smoke and bio-aerosols for perioperative nurses in Thailand. Journal of Perioperative Nursing, 31(1), 33-41.

Aydın, N, Kaya, U, Dal Yılmaz, Ü. (2021). The Effect of Surgical Smoke on Operating Room Staff. Medical Journal of Western Black Sea, 5(1), 80-85.

Ball, K. (2010). Surgical smoke evacuation guidelines: compliance among perioperative nurses. AORN journal, 92(2), e1-e23.

Benson, SM, Maskrey, JR, Nembhard, MD, Unice, KM, Shirley, MA, Panko, JM. (2019). Evaluation of personal exposure to surgical smoke generated from electrocautery instruments: a pilot study. Annals of Work Exposures and Health, 63(9), 990-1003.

Beswick, A, Evans, G. (2012). Evidence for exposure and harmful effects of diathermy plumes (surgical smoke). Buxton: Health & Safety Executive.

Bree, K, Barnhill, S, Rundell, W. (2017). The dangers of electrosurgical smoke to operating room personnel: a review. Workplace health & safety, 65(11), 517-526.

Canicoba, ARB, de Brito Poveda, V. (2021). Surgical Smoke and Biological Symptoms in Healthcare Professionals and Patients: A Systematic Review. Journal of PeriAnesthesia Nursing, 37(1), 130-136.

Claudio, CV, Ribeiro, RP, Martins, JT, Marziale, MHP, Solci, MC, Dalmas, JC. (2017). Polycyclic aromatic hydrocarbons produced by electrocautery smoke and the use of personal protective equipment 1. Revista latino-americana de enfermagem, 25.

Comprehensive meta-analysis (n.d.). Retrieved April 4, 2022, from https://www.meta analysis.com/pages/demo.php

Critical appraisal tools. JBI. (n.d.). Retrieved October 23, 2022, from https://jbi.global/critical-appraisal-tools

DerSimonian, R, Laird, N. (1986). Meta-analysis in clinical trials. Controlled clinical trials, 7(3), 177-188.

Dinçer S. (2014). Applied Meta-Analysis in Educational Sciences. (1st ed.). Ankara: Pegem Academy Publishing.

Edwards, BE, Reiman, RE. (2008). Results of a survey on current surgical smoke control practices. AORN journal, 87(4), 739-749.

Fox-Lewis, A, Allum, C, Vokes, D, Roberts, S. (2020). Human papillomavirus and surgical smoke: a systematic review. Occupational and Environmental Medicine, 77(12), 809-817.

Georgesen, C, Lipner, SR. (2018). Surgical smoke: risk assessment and mitigation strategies. Journal of the American Academy of Dermatology, 79(4), 746-755.

Hahn, KY, Kang, DW, Azman, ZAM, Kim, SY, Kim, SH. (2017). Removal of hazardous surgical smoke using a built-in-filter trocar: a study in laparoscopic rectal resection. Surgical Laparoscopy Endoscopy & Percutaneous Techniques, 27(5), 341-345.

Ilce, A, Yuzden, GE, Van Giersbergen, MY. (2017). The examination of problems experienced by nurses and doctors associated with exposure to surgical smoke and the necessary precautions. Journal of Clinical Nursing, 26(11-12), 1555-1561.

Keeley, L, Smalley, P. (2022). Occupational hazards of surgical smoke plume in the operating theatre. Surgical Plume Alliance 4-5.

Kılıç, S. (2015). Kappa test. Psychiatry and Behavioral Sciences, 5(3), 142.

Lindsey, C, Hutchinson, M, Mellor, G. (2015). The nature and hazards of diathermy plumes: a review. AORN journal, 101(4), 428-442.

Liu, N, Filipp, N, Wood, KB. (2020). The utility of local smoke evacuation in reducing surgical smoke exposure in spine surgery: a prospective self-controlled study. The Spine Journal, 20(2), 166-173.

Mowbray, N, Ansell, J, Warren, N, Wall, P, Torkington, J. (2013). Is surgical smoke harmful to theater staff? A systematic review. Surgical endoscopy, 27(9), 3100-3107.

Navarro-Meza, MC, González-Baltazar, R, Aldrete-Rodríguez, MG, Carmona-Navarro, DE, López- Cardona, MG. (2013). Síntomas respiratorios causados por el uso del electrocauterio en médicos en formación quirúrgica de un hospital de México. Revista Peruana de Medicina Experimental y Salud Pública, 30(1), 41-44.

Oberg, T, Brosseau, LM. (2008). Surgical mask filter and fit performance. American journal of infection control, 36(4), 276-282.

Olgun, Ş. (2020). Surgıcal smoke, precautıons and employee awareness. Journal of Awareness, 5(1), 65.

OSHA (The Occupational Safety and Health Administration). Laser/Electrosurgery Plume (n.d.). Retrieved October 21, 2022, from https://www.osha.gov/laser-electrosurgery-plume/standards

Pillinger, SH, Delbridge, L, Lewis, DR. (2003). Randomized clinical trial of suction versus standard clearance of the diathermy plume. Journal of British Surgery, 90(9), 1068-1071.

Saito, AC, Margatho, AS, Bieniek, AA, Stanganelli, NC, Ribeiro, RP. (2019). Signs and symptoms related to inhalation of surgical smoke in the nursing team. Escola Anna Nery, 23.

Smith, JD, MacDougall, CC, Johnstone, J, Copes, RA, Schwartz, B, Garber, GE. (2016). Effectiveness of N95 respirators versus surgical masks in protecting health care workers from acute respiratory infection: a systematic review and meta-analysis. Cmaj, 188(8), 567-574.

Spearman, J, Tsavellas, G, Nichols, P. (2007). Current attitudes and practices towards diathermy smoke. The Annals of the Royal College of Surgeons of England, 89(2), 162-165.

Stanganelli, NC, Bieniek, AA, Margatho, AS, Galdino, MJQ, Barbosa, KH, Ribeiro, RP. (2019). Inhalation of surgical smoke: cohort of signs and symptoms in residents. Acta Paulista de Enfermagem, 32, 382-389.

Stanley, K. (2019). Diathermy smoke shown to be hazardous, so why are we not protecting ourselves? Journal of perioperative practice, 29(10), 321-327.

Tseng, HS, Liu, SP, Uang, SN, Yang, LR, Lee, SC, Liu, YJ, Chen, DR. (2014). Cancer risk of incremental exposure to polycyclic aromatic hydrocarbons in electrocautery smoke for mastectomy personnel. World Journal of Surgical Oncology, 12(1), 1-8.

Usta, E, Aygin, D, Bozdemir, H, Uçar, N. (2019). The effects of surgical smoke in operating rooms and precautions for protection Journal of Health Science and Profession, 6(1), 17-24.

Ünver, S, Topçu, SY, Fındık, ÜY. (2016). Surgical smoke, me and my circle. International Journal of Caring Sciences, 9(2), 697-703.

Van Gestel, EA, Linssen, ES, Creta, M, Poels, K, Godderis, L, Weyler, JJ, ... Vanoirbeek, JA. (2020). Assessment of the absorbed dose after exposure to surgical smoke in an operating room. Toxicology Letters, 328, 45-51.

Van Giersbergen, MY, Alcan, AO, Kaymakci, S, Ozsaker, E, Dirimese, E. (2019). Investigation of surgical smoke symptoms and preventive measures in Turkish operating rooms. International Journal of Health Sciences and Research, 9(1), 138-144.

Van Giersbergen, M, Şahin Köze, B. (2022). Surgical Smoke. In Van Giersbergen, MY, Kaymakçı, Ş. (Eds.). Operating Room Nursing (pp. 295-308). İzmir: Turkish Society of Surgical and Operating Room Nurses.

Xie, W, Dumas, O, Varraso, R, Boggs, KM, Camargo, CA, Stokes, AC. (2021). Association of Occupational Exposure to Inhaled Agents in Operating Rooms with Incidence of Chronic Obstructive Pulmonary Disease among US Female Nurses. JAMA network open, 4(9), e2125749-e2125749.