

# SIGNS AND SYMPTOMS RELATED TO SURGICAL SMOKE EXPOSURE: INTEGRATIVE REVIEW

*Sinais e sintomas relacionados à exposição à fumaça cirúrgica: revisão integrativa*

*Signos y síntomas relacionados con la exposición al humo quirúrgico: revisión integrativa*

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**ABSTRACT: Objective:** To analyze the scientific evidence available in the literature on signs and symptoms related to surgical smoke exposure among surgical block workers. **Method:** This integrative literature review searched the following databases: MEDLINE, Cumulative Index to Nursing and Allied Health Literature, Latin American and Caribbean Health Sciences Literature, Web of Science, and Scopus. **Results:** A total of 1,351 studies were pre-selected, 4 of which were found by manual search. In the end, five articles were analyzed. The signs and symptoms identified were: cough, burning sensation in the pharynx, sneezing, rhinitis, nasopharyngeal lesion, foreign body sensation in the throat, nasal congestion, airway inflammation, lacrimation, nausea, vomiting, abdominal pain, weakness, muscle cramp, headache, drowsiness, lightheadedness, irritability, discomfort (such as unpleasant smell in clothes). **Conclusion:** Great advances have been detected in the studies proposed. These investigations lay the foundation for the intensity of signs and symptoms and the orientation regarding harmful risks, providing managers with the knowledge and scientific basis for future interventions, both to protect the team and to prevent risks in the work environment. **Keywords:** Signs and symptoms. Smoke. Electrosurgery. Electrocoagulation. Occupational health.

**RESUMO: Objetivo:** Analisar as evidências científicas disponíveis na literatura sobre os sinais e sintomas relacionados à exposição à fumaça cirúrgica em trabalhadores do bloco operatório. **Método:** Revisão integrativa da literatura, com busca nas seguintes bases de dados: Medline, Cumulative Index to Nursing and Allied Health Literature, Literatura Latino-Americana e do Caribe em Ciências da Saúde, Web Of Science e SCOPUS. **Resultados:** Foram 1.351 estudos pré-selecionados, sendo 4 por busca manual. Ao fim, obtiveram-se cinco artigos para análise. Os sinais e sintomas encontrados foram: tosse, ardência de faringe, espirros, rinite, lesão nasofaringe, sensação de corpo estranho na garganta, congestão nasal, inflamação das vias aéreas, lacrimejamento dos olhos, náuseas, vômitos, dor abdominal, fraqueza, cãibra, cefaleia, sonolência, tonturas, irritabilidade, desconforto (como mau cheiro na roupa). **Conclusão:** Observaram-se grandes avanços nas pesquisas propostas, estudos que embasam a intensidade dos sinais e sintomas e orientação dos riscos nocivos que proporcionem aos gestores conhecimento e fundamentação científica para futuras intervenções tanto contra a proteção ao trabalhador como para prevenção de risco no ambiente de trabalho. **Palavras-chave:** Sinais e sintomas. Fumaça. Eletrocirurgia. Eletrocoagulação. Saúde do trabalhador.

**RESUMEN: Objetivo:** Analizar la evidencia científica disponible en la literatura sobre signos y síntomas relacionados con la exposición al humo quirúrgico en trabajadores de quirófano. **Método:** Revisión integrativa de la literatura, buscando en las siguientes bases de datos: Medline, Cumulative Index to Nursing and Allied Health Literature, Latin American and Caribbean Literature in Health Sciences, Web Of Science y SCOPUS. **Resultados:** Hubo 1.351 estudios preseleccionados, cuatro por búsqueda manual. Al final, se obtuvieron cinco artículos para su análisis. Los signos y síntomas encontrados fueron: tos, ardor faríngeo, estornudos, rinitis, lesión nasofaríngea, sensación de cuerpo extraño en la garganta, congestión nasal, inflamación de las vías respiratorias, lagrimeo de los ojos, náuseas, vómitos, dolor abdominal, debilidad, calambres, dolor de cabeza, somnolencia, mareos, irritabilidad, malestar como mal olor en la ropa. **Conclusión:** Hubo grandes avances en la investigación propuesta, estudios que apoyan la intensidad de los signos y síntomas y orientaciones sobre riesgos nocivos que brinden a los gestores conocimiento y fundamento científico para futuras intervenciones, tanto contra la protección del trabajador como para la prevención de riesgos en el entorno laboral. **Palabras clave:** Signos y síntomas. Humo. Electrocirurgia. Eletrocoagulación. Salud laboral.

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## INTRODUCTION

Electrocautery is a high-frequency electronic device capable of cutting, dissecting, and coagulating tissues and vessels. It is often used in different surgical procedures given its advantages, as, in addition to reducing the risk of bleeding, it also helps visualize the surgical site and decreases surgical time<sup>1</sup>.

When the electrocautery burns the tissue, it produces surgical smoke, in which potentially carcinogenic toxic chemical compounds, such as formaldehyde, hydrogen cyanide, benzene, and carbon monoxide, as well as cell materials and viral particles, have been identified<sup>2</sup>.

The presence of these compounds in surgical smoke represents risks to workers exposed during surgical procedures, with complications to their health, even when they use personal protective equipment (PPE), such as surgical masks and glasses<sup>3</sup>, as is usually the case in surgical centers (SC).

A literature review on the use of an electric scalpel and the related nursing care identified the employees' and nurses' lack of knowledge regarding its handling and operation<sup>4</sup>, impacting the risk to the worker's health.

A study carried out in a Mexican hospital with 115 resident physicians of all surgical specialties, where electrocautery is used in 70% of surgical procedures, the authors found the following signs and symptoms: foreign body sensation in the throat, burning sensation in the pharynx, nausea, vomiting, nasal congestion, headache, eye irritation, irritation in other mucous membranes, sneezing, weakness, and lightheadedness<sup>1</sup>.

This study detected the need to define sign and symptom: a sign is an objective account, that is, a reported and identified complaint, while symptom indicates a subjective sensation of abnormality<sup>5</sup>.

According to these researchers' experience, the workers have actually reported other signs and symptoms besides those described. The explanation for these signs and symptoms helps understand the risks involved in the exposure of health professionals to surgical smoke. In addition, these results can potentially contribute to the development of strategies to improve workers' health. Therefore, a systematic search for more scientific findings involving this theme is necessary.

## OBJECTIVE

To analyze the scientific evidence available in the literature on signs and symptoms related to surgical smoke exposure among surgical block workers.

## METHOD

### Study design

The present study is an integrative literature review that gathered and summarized the knowledge produced by several articles, in addition to pointing out gaps in the knowledge of the theme that could be investigated in new research<sup>6</sup>.

The following steps guided the study: choosing the theme and defining the objective, elaborating the guiding question of the research, searching databases to identify primary research according to the eligibility criteria for the studies, and, at the end of the process, performing the critical analysis of the studies included<sup>6</sup>.

### Theme identification and selection of the hypothesis or research question to elaborate the integrative review

The current study proposed the following research question to guide the review: what are the consequences of the signs and symptoms presented by health professionals exposed to surgical smoke?

We elaborated the research question based on the PICO strategy, an acronym for: Patients, which, in this study, corresponded to "health workers"; Interventions — "electrocautery"; Comparison, which does not apply to the objective of the study; Outcomes, represented by "consequences related to signs and symptoms"<sup>7</sup>.

This study defined the terms sign and symptom as follows: sign is an objective account, that is, a reported and identified complaint; symptom indicates a subjective sensation of abnormality<sup>5</sup>.

### Data collection procedure

The databases selected for the search for primary studies were: Scopus, National Library of Medicine – National Institutes of Health (MEDLINE) via PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Latin American and Caribbean Health Sciences Literature (LILACS), and Web of Science (WOS). We also included studies retrieved by manual search in the analysis of this review. They are part of the database of the Occupational Health Research Center at Universidade Estadual de Londrina (NUESTUEL).

The strategy used to search for studies in the databases was based on controlled keywords of the Health Sciences Descriptors

(*Descritores em Ciências da Saúde — DeCS*): *eletrocirurgia, eletrocoagulação, saúde do trabalhador*; and of the Medical Subject Headings (MeSH): *electrosurgery, electrocoagulation, surgical smoke, symptoms and signs, health occupation*. The non-controlled keywords searched in DeCS were: *fumaça cirúrgica, fumaça, terapia a laser, cauterização, sinais e sintomas, exposição ocupacional, segurança do trabalho, segurança ocupacional, bisturi a laser, eletrocautério, manifestações clínicas, sinais clínicos, queixas e sintomas, exposição laboral a agentes químicos, físicos ou biológicos*; and in MeSH were: *smoke, laser therapy, cautery, electrocautery, smoke evacuation, thermocoagulation, galvanocautery, surgical diathermy, endocavitary fulguration, personnel health, healthcare worker, health professions*.

For the correlations between terms, we used the boolean operators “AND” and “OR” to obtain a refined search and a greater number of articles that could potentially answer the guiding question. The search was carried out from May to June 2018.

A broad literature search was performed, with no limitations as to language or year of publication. This research included only primary studies.

## Selection criteria

The articles were selected first by reading the titles and abstracts and, later, the full texts. Two independent reviewers selected the articles, and, in case of issues, a third reviewer reassessed the studies.

## Data analysis and treatment

We considered the following items to evaluate the level of evidence of the articles:

- level 1: evidence from a systematic review of all relevant randomized clinical trials or clinical practice guidelines based on evidence from systematic reviews;
- level 2: evidence obtained from at least one well-designed randomized clinical trial;
- level 3: evidence obtained from well-designed controlled clinical trials, without randomization, and quasi-experimental studies;
- level 4: evidence from well-designed case-control and cohort studies;
- level 5: evidence from systematic reviews of descriptive and qualitative studies;
- level 6: evidence from a single descriptive or qualitative study;

- level 7: evidence from authorities' opinions and/or expert committee reports<sup>7</sup>.

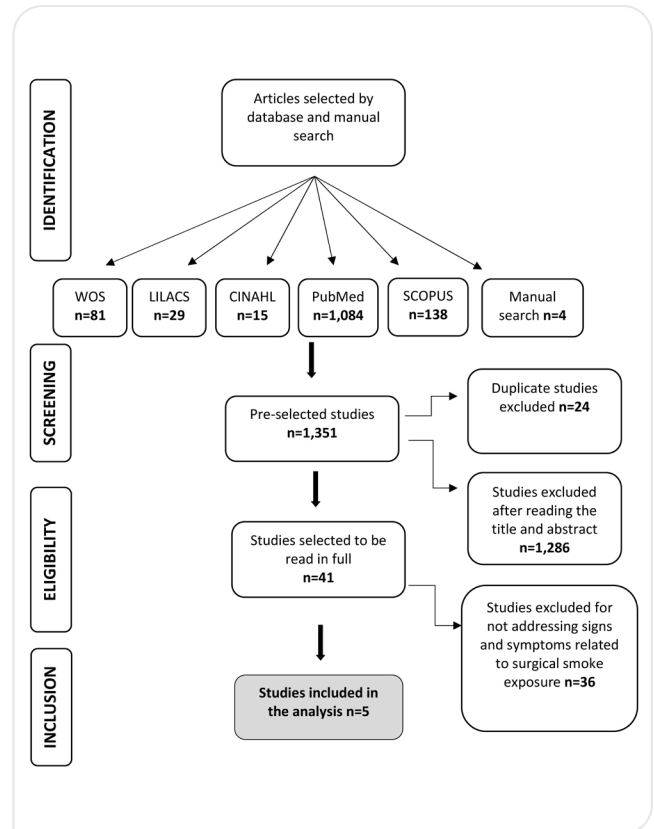
This review did not include articles with levels of evidence 1, 5, and 7.

The current study followed the steps proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist<sup>8</sup>.

Figure 1 represents the flow diagram of the path followed for identification, screening, and inclusion of primary studies, according to the databases listed.

## RESULTS

To present the results, we chose to identify the studies by letter E, corresponding to the word *estudo* (study), with a numerical sequence from one to five. Among the 5 primary studies selected, all were published in the past 12 years, 3 studies were in Turkish (60%), 2 in English (40%), and 1 in Spanish (20%).



**Figure 1.** Flow diagram of studies in the integrative review.

As for design, they were all classified as descriptive observational studies, with a quantitative approach, thus falling into the scientific level of evidence 6.

Chart 1 summarizes the studies selected to comprise this review, according to authors, country, population, and signs and symptoms related to surgical smoke exposure.

In addition to the signs and symptoms presented in Chart 1, some studies described diseases related to surgical smoke exposure, such as anemia, rhinitis, asthma, conjunctivitis, dermatitis, cardiovascular diseases, hepatitis, and cancer.

Table 1 presents the signs and symptoms related to surgical smoke exposure.

**Chart 1.** Summary of the selected studies according to authors, country, population, and signs and symptoms related to surgical smoke exposure.

Study	Population/sample	Signs and symptoms
E1 – Navarro-Meza et al., 2013 <sup>1</sup> (Mexico)	Resident physicians: 50	- Foreign body sensation in the throat: 58.0% - Burning sensation in the pharynx: 22.0% - Nausea: 4.0% - Nasal congestion: 2.0%
E2 – İlce et al., 2017 <sup>9</sup> (Turkey)	Nurses: 45 Physicians: 36	- Headache (nurses: 48.9%; physicians: 58.3%) - Lacrimation (nurses: 40.0%; physicians: 41.7%) - Cough (nurses: 48.9%; physicians: 27.8%) - Burning sensation in the pharynx (nurses: 40.0%; physicians: 38.9%) - Nausea (nurses: 44.4%; physicians: 30.6%) - Other*
E3 – Ünver et al., 2016 <sup>10</sup> (Turkey)	Nurses: 54	- Headache 59.3% - Pharyngeal irritation: 56.6% - Nausea: 40.7% - Lacrimation: 38.9% - Weakness: 24.1% - Lightheadedness: 9.3%
E4 – Usta et al., 2019 <sup>11</sup> (Turkey)	Nurses: 105	- Headache 61.9% - Nausea: 39% - Vomiting: 14.3% - Cough: 41.0% - Eye irritation: 54.3% - Burning sensation in the pharynx: 43.8% - Irritability: 29.5% - Lightheadedness: 32.4% - Respiratory problems: 27.6% - Nasopharyngeal lesion: 7.6% - Weakness: 25.7% - Muscle cramp: 22.9% - Abdominal pain: 15.2%
E5 – Okgün Alcan et al., 2017 <sup>12</sup> (Turkey)	Nurses: 71	- Headache 71.8% - Nausea: 63.4% - Cough: 57.7% - Burning sensation in the pharynx: 49.3% - Lacrimation: 46.5% - Sneezing: 39.4% - Lightheadedness: 38.0% - Irritability: 31.0% - Airway inflammation: 29.6% - Weakness: 28.2% - Nasopharyngeal lesion: 7.0% - Vomiting: 5.6% - Abdominal pain: 8.5% - Muscle cramp: 9.9%

\*Others: drowsiness, lightheadedness, sneezing, weakness, irritation, nasopharyngeal lesion, abdominal pain, vomiting.

In most of the five studies in the review, the respiratory system had the highest incidence of signs and symptoms when the professional was exposed to surgical smoke, followed by the visual system.

## DISCUSSION

A descriptive study analyzing the gaseous by-products present in surgical smoke found that, due to their aerodynamic size, the particles generated — and inhaled by health workers and patients — traveled a distance of up to 100 cm from their site of production<sup>13</sup>. Also, 1 g of cauterized tissue causes a surgical smoke plume with mutagenic effects, equivalent to smoking from three to six unfiltered cigarettes<sup>14,15</sup>.

In addition, the highest incidence of signs and symptoms found in this study was associated with the respiratory system. This result may be connected to the fact that inhalation of surgical smoke can penetrate the lung, leading to chronic and acute diseases, such as alveolar congestion, interstitial pneumonia, and bronchiolitis<sup>13</sup>.

The same study reports that acrylonitrile and carbon monoxide (CO) are among the concerning chemicals most found in surgical smoke. They are responsible for signs and symptoms such as eye irritation, nausea, vomiting, headache, sneezing, weakness, and lightheadedness, and prolonged exposure to them can produce irritation and dermatitis. These signs and symptoms are related to the respiratory and integumentary systems<sup>13</sup>.

Physiologically, the gas exchange process occurs during the ventilation and inhalation of air into the alveoli, which are surrounded by capillary vessels, with the exchange happening in the interface between the alveolar epithelium, interstice, and tissue capillary<sup>16</sup>. Therefore, the respiratory

system becomes the main target when exposed to surgical smoke, probably due to the size of the oxidizing particles present in it.

Particles with less than 10 µm diameter dissipated in the environment can be inhaled and have the potential of impairing the respiratory tract; those below 2.5 µm reach the pulmonary alveoli when inhaled; particles with diameters even smaller than 0.01 µm, characterized as ultra-fine particles (UFP), spread in surgical smoke can penetrate deeper into the respiratory system, leading to greater involvement of this system<sup>1,17-20</sup>.

The acrylonitrile chemical compound, present in the surgical plume, has a toxic effect when inhaled due to the formation of cyanide, responsible for discomforts such as eye irritation, nausea, vomiting, headache, sneezing, weakness, and lightheadedness. Prolonged exposure to this compound can be potentially carcinogenic and causes irritation and dermatitis<sup>13</sup>.

More commonly found in laparoscopic procedures, the CO chemical is absorbed by the cells and directed to the bloodstream. Combined with hemoglobin, it triggers a systemic hypoxic stress response, resulting in decreased oxygen transport capacity within the body. In individuals with cardiovascular diseases, it can be even more harmful<sup>13,21</sup>.

The characteristic of the chemical is directly related to the type of tissue in which the electrocautery was used. Adipose tissues produce more aldehydes and less toluene, leading to greater development of signs and symptoms<sup>22</sup>.

A proven case revealed that, after treating a patient with anogenital warts using laser, the surgeon developed laryngeal papillomatosis. Investigations were carried out and identified the presence of human papillomavirus (HPV) type 6 and 11 in the patient, the same ones found in the surgeon's larynx; with no other possible trigger for the disease, the occupational risk to this

**Table 1.** Signs and symptoms identified in the five studies selected for this review, grouped by systems.

Studies in the review	Signs and symptoms	Respiratory system	Visual system	Digestive system	Musculoskeletal system	Nervous system
	n	n (%)	n (%)	n (%)	n (%)	n (%)
E1	04	03 (75.0)	-	01 (25.0)	-	-
E2	13	04 (30.8)	01 (7.7)	03 (23.0)	01 (7.7)	04 (30.8)
E3	06	01 (16.6)	01 (16.6)	01 (16.6)	01 (16.6)	02 (33.2)
E4	13	04 (30.8)	01 (7.8)	03 (23.0)	02 (15.4)	03 (23.0)
E5	14	04 (28.6)	02 (14.3)	03 (21.4)	02 (14.3)	03 (21.4)

professional was characterized<sup>23</sup>. The exposure time for its development is unknown, but the literature reports that the HPV incubation period can range from 2 to 8 months, and clinical signs and symptoms may take up to 20 years to develop<sup>24</sup>.

None of the articles analyzed in this review described the presence of a surgical smoke evacuation system in operating rooms, as recommended by world organizations. Some studies report the use of an aspiration catheter to aspirate surgical smoke, which has no evidence of protection against risks. In one of the studies, the authors stated that 92.5% of the professionals knew about the existence of surgical smoke, and 55.6% were aware of the harmful risk of exposure to these substances<sup>12,25</sup>.

The diseases resulting from inhalation of surgical smoke are: emphysema, asthma, bronchitis, dermatitis, cardiovascular dysfunction, anemia, leukemia, nasal lesion, human immunodeficiency virus (HIV) infection, and hepatitis. Surgical smoke cumulates in the human body; therefore, the longer the exposure, the greater the risk<sup>13,26</sup>.

The literature reports several harmful effects related to surgical smoke; however, it lacks evidence and consistent recommendations for protecting workers from exposure to surgical smoke<sup>27</sup>.

The Occupational Safety and Health Administration (OSHA) recommends using surgical masks to capture particles larger than 5 mm. This type of mask does not protect against all compounds present in surgical smoke, as it has no seal or filter. Thus, the surgical mask is not adequate to protect against surgical smoke<sup>13,27</sup>.

Regarding surgical smoke evacuation, OSHA has no specifications on filtration by equipment, but other organizations, such as the Association of PeriOperative Registered Nurses (AORN), support a surgical smoke filtration system and aerosols at high concentrations<sup>25,28</sup>. Other recommendations include engineering control, that is, the ventilation of operating rooms: 20 air changes/hour<sup>29</sup>.

The smoke evacuation system and the devices should be used following the manufacturer's instructions. In high concentrations of surgical smoke with UFP smaller than 0.01 µm, filters should be used for smoke evacuation. Thus, for small smoke concentrations, the worker should use a surgical vacuum system with a 0.1 µm filter installed between the suction wall connection and the suction container. Therefore, the smoke capture device must be as close as possible to the surgical site so as to collect the surgical smoke, harmful to the professional's health<sup>30</sup>.

The Guideline recommends the use of a set of protective measures to reduce the occupational risk to workers exposed to surgical smoke, including surgical smoke evacuation systems with air filtration and the use of a mask that protects against particles with 0.01 µm diameter, namely, masks with a 95% particle filtration, known as N95<sup>25</sup>.

Proposals for the use of N95 may protect professionals exposed to surgical smoke. Nevertheless, compliance with this measure is poor since masks with 95% filtration are uncomfortable. Consequently, the workers do not recognize the risk of exposure to surgical smoke<sup>31</sup>.

Furthermore, the lack of risk recognition, the workers' discomfort when using PPEs<sup>31</sup>, and the lack of studies indicating the best ways of preventing this risk make it difficult to protect health professionals from falling ill.

Concerning study limitations, we underline the lack of standardization of data collection instruments in the studies selected for this review, as well as of signs and symptoms related to surgical smoke exposure, as, in most articles, they were confused with diseases. Thus, further studies with strong scientific evidence are necessary, as they might provide elements for future research to substantiate this theme. There is a knowledge gap regarding the surgical smoke exposure time for developing clinical signs and symptoms. New discoveries have been unveiled, but no consensus has been reached about exposure time.

We also highlight the scarcity of studies with scientific rigor so as to qualify the research as strong for a reasoned discussion.

## CONCLUSION

Given the objective of the current study, the consequences of surgical smoke exposure for the worker is the development of signs and symptoms identified in this review, such as: cough, burning sensation in the pharynx, sneezing, rhinitis, nasopharyngeal lesion, foreign body sensation in the throat, nasal congestion, airway inflammation, lacrimation, nausea, vomiting, abdominal pain, weakness, muscle cramp, dermatitis, headache, drowsiness, lightheadedness, irritability, discomfort (e.g., unpleasant smell in clothes). Some diseases stand out, including anemia, rhinitis, conjunctivitis, cardiovascular diseases, hepatitis, and cancer.

Great advances are expected in the research about this theme with the development of this study. Research that

lays the foundations for the intensity of signs and symptoms triggered in professionals exposed to surgical smoke and the consequent orientation regarding harmful risks, providing

managers with the knowledge and scientific basis for future interventions, both to protect the team and to prevent risks in the work environment.

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