

Occupational risk: signs and symptoms related to exposure to surgical smoke*

Risco ocupacional: sinais e sintomas relacionados à exposição à fumaça cirúrgica

Riesgo laboral: signos y síntomas relacionados con la exposición al humo quirúrgico

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ABSTRACT: Objective: To identify the prevalence and intensity of signs and symptoms related to occupational exposure to surgical smoke in health workers and their protective measures. **Method:** Descriptive cross-sectional study, developed with healthcare workers exposed to surgical smoke. Collection was carried out in September 2021, in a tertiary service institution with oncological and philanthropic characteristics and in a highly complex university hospital. **Results:** The sample consisted of 155 participants; the prevalence of signs and symptoms was: respiratory system 55.45%, ocular system 43.22%, and nervous system 37.41%, with statistical significance for the intensity of signs and symptoms in the integumentary ($p=0,05$) and nervous ($p=0,01$) systems. **Conclusions:** The highest rate of prevalence of signs and symptoms was in the respiratory, ocular, nervous, and integumentary systems with statistical significance.

Keywords: Electrosurgery. Smoke. Signs and symptoms. Occupational health.

RESUMO: Objetivo: Identificar a prevalência e a intensidade dos sinais e sintomas relacionados à exposição ocupacional à fumaça cirúrgica em trabalhadores da saúde e suas medidas de proteção. Método: Estudo transversal de caráter descritivo, desenvolvido com trabalhadores da área da saúde expostos à fumaça cirúrgica. A coleta foi realizada em setembro de 2021, em uma instituição de serviço terciário com característica oncológica e filantrópica e em um hospital universitário de alta complexidade. Resultados: A amostra foi de 155 participantes, a prevalência de sinais e sintomas: sistema respiratório de 55,45%, sistema ocular 43,22% e sistema nervoso 37,41%, com significância estatística para a intensidade de sinais e sintomas nos sistemas tegumentar ($p=0,05$) e nervoso ($p=0,01$). Conclusão: A maior taxa de prevalência dos sinais e sintomas foi nos sistemas respiratório, ocular, nervoso e tegumentar com significância estatística.

Palavras-chave: Eletrocirurgia. Fumaça. Sinais e sintomas. Saúde do trabalhador.

RESUMEN: Objetivo: Identificar la prevalencia e intensidad de los signos y síntomas relacionados con la exposición ocupacional al humo quirúrgico en trabajadores de la salud y sus medidas de protección. Método: Estudio transversal descriptivo, desarrollado con trabajadores de la salud expuestos al humo quirúrgico. La colecta se realizó en septiembre de 2021, en una institución de tercer nivel con características oncológicas, filantrópicas y en un hospital universitario de alta complejidad. Resultados: La muestra estuvo conformada por 155 participantes, La prevalencia de signos y síntomas: Sistema respiratorio 55,45%, sistema ocular 43,22% y sistema nervioso 37,41%, con significación estadística para la intensidad de signos y síntomas en los sistemas tegumentarios ($p=0,05$) y nervioso ($p=0,01$). Conclusión: La mayor tasa de prevalencia de signos y síntomas fue en los sistemas respiratorio, ocular, nervioso y tegumentario con significancia estadística.

Palabras clave: Electrocirugía. Humo. Signos y síntomas. Salud laboral.

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INTRODUCTION

Hospital environment provides health workers with exposure to various occupational hazards, classified as: chemical, physical, biological, ergonomic, and psychosocial. The surgical center (SC) is considered a critical area of a hospital service, with various types of technologies, which exposes workers to severe risks to their health^{1,2}.

As an example of technology, there is the electric scalpel, which assists in surgical procedures³. With the use of the electric scalpel for tissue dissection, cutting and coagulation, surgical smoke is generated, consisted of a gaseous by-product⁴. According to the functions performed by these devices, target cells are heated to the boiling point (100°C), resulting in the disruption of cell membranes, and consequently the ultrafine particles (surgical smoke) are dispersed in the environment⁵.

Surgical smoke is composed of 95% water vapor and 5% particulate matter⁶, namely: chemical compounds (formaldehyde, hydrogen cyanides, benzene, and carbon monoxide) and biological compounds (cell material and virus particles)⁷. The amount of surgical smoke production and the chemical constituents are directly proportional to the type of surgery, tissue, type of energy, and duration of surgery⁸.

Evidence from the literature illustrates that occupational exposure to these chemical agents can trigger signs and symptoms in exposed workers, such as: cough, pharyngeal burning, sneezing, rhinitis, nasopharyngeal injury, sensation of a foreign body in the throat, nasal congestion, inflammation of the airways, tearing eyes, nausea, vomiting, abdominal pain, weakness, cramps, dermatitis, headache, drowsiness, dizziness, irritability, discomfort (such as bad smell in clothes and hair); in addition to diseases such as: anemia, rhinitis, conjunctivitis, cardiovascular problems, hepatitis, and cancer⁹. For the protection of these workers, it is necessary to use protective equipment, such as N-95 or PFF2 masks, smoke vacuum cleaners in operating rooms and the use of protective goggles¹⁰.

Therefore, the aim of this study was to identify the prevalence and intensity of signs and symptoms related to occupational exposure to surgical smoke in health workers and their protective measures.

OBJECTIVE

To identify the prevalence and intensity of signs and symptoms related to occupational exposure to surgical smoke in health workers and their protective measures.

METHOD

This is a cross-sectional study. Data collection was carried out in two institutions in the northern region of Paraná. Institution I is philanthropic, oncological, serves 166 municipalities in the north of Paraná, of a highly complex nature, responsible for performing an average of 573 surgical procedures per month. It presents a team of workers occupationally exposed to surgical smoke, composed of 56 employees in the nursing area (52 nursing technicians and 4 nurses, 1 of which is a managerial nurse) and 50 surgeons. The surgical center is open from Monday to Saturday, with procedures for the Unified Health System (*Sistema Único de Saúde – SUS*) performed from Monday to Friday, and Saturdays for private procedures and emergencies.

Institution II represents a highly complex university hospital, serving patients from approximately 250 municipalities in northern Paraná and from more than 100 cities in other states, mainly from São Paulo, Mato Grosso, Mato Grosso do Sul, and Rondônia. Responsible for performing an average of 588 surgical procedures per month, it has 193 employees occupationally exposed to surgical smoke, of which 63 are surgeons, 40 medical residents, 32 anesthesiologists, 40 nursing technicians, and 18 nurses. The surgical center has seven operating rooms, one of which is intended only for urgent and emergency procedures, both operating 24 hours a day.

Data collection was carried out in September 2021, using two instruments: sociodemographic characterization and Scale for Assessing the intensity of Signs and Symptoms related to Exposure to Surgical Smoke (*Escala para Avaliação da intensidade dos Sinais e Sintomas relacionados à Exposição à Fumaça Cirúrgica – EASE*).

The sociodemographic characterization instrument presents as variables: age, gender, profession, education, area of activity, time in the area of activity, and protection measures.

EASE is composed of 33 items, subdivided into six areas, namely: respiratory system (10 items), ocular (9 items), digestive (3 items), musculoskeletal (2 items), integumentary (4 items), and nervous (5 items). The scale is numerically measured, ranging from 0 to 3, with 0 (no signs and symptoms), 1 (low intensity), 2 (moderate intensity), and 3 (high intensity), corresponding to the evaluated signs and symptoms. This scale was validated for content, appearance and relevance by experts in SC and in scale development and validation, with a Content Validity Index above 0.9 (90%)¹¹.

Health workers exposed to surgical smoke were included in the study and students, hygiene workers, and pharmacy professionals were excluded, as they had a different work process and exposure compared to nursing workers.

Collected data were tabulated in Microsoft Excel for Windows® and analyzed using the Statistical Package for the Social Sciences (SPSS) version 22.0 and the Statistical Analysis System (SAS) for Windows® version 9.3.

In the crude analysis, the relationship between the outcomes and the variables age, gender, profession, education, area of expertise, time in the area of expertise, protective measures, and the presence of signs and symptoms related to exposure to surgical smoke was verified. For this, χ^2 tests for heterogeneity and linear trend were used. At first, the variables age, gender, profession, education, area of activity, time in the area of activity, and protection measures were analyzed; then, the variable presence of signs and symptoms. The variables that presented $p < 0.05$ in the multivariable analysis remained in the final model.

Workers were first approached with a presentation of the research, followed by the Informed Consent document. After agreeing and signing the term, they were instructed to fill in the sociodemographic characterization instrument and EASE. At the end, the scale score and its representativeness were clarified.

The research project was analyzed and approved by the Permanent Committee on Ethics in Research with Human Beings (*Comitê Permanente de Ética em Pesquisa com Seres Humanos* – COPEP), of Universidade Estadual de Londrina (PR), with CAAE 13656719.0.0000.5231, opinion number 4.892.743, as well as respecting the ethical precepts of Resolution 466/12 of the National Health Council (*Conselho Nacional de Saúde* – CNS).

RESULTS

The population eligible to participate in this study consisted of 179 workers, of whom 24 were excluded, 14 did not meet the selection criteria, and 10 did not accept to participate in the research.

The sample consisted of 155 workers, 67 of whom belong to institution I and 88 to institution II, 51.6% ($n=80$) were females and mean age was 37 years. The working time in the sector was, on average, 42 years. A total of 89 (57.42%) surgeons participated in the survey, followed by 52 (33.55%) nursing technicians, and 14 (9.03%) nurses.

Regarding the education of these workers, 46.45% ($n=72$) had specialization, 27.09% ($n=42$) were graduated, 20.64% ($n=32$) had a technical level, and 5.82% ($n=9$) had a master's and/or doctorate degree.

Regarding the presence of signs and symptoms, it was observed that 28.4% ($n=44$) of the workers at institution I and 36.8% ($n=57$) of the workers at institution II stated that they felt some symptom that could be related to occupational exposure to surgical smoke, as shown in Table 1.

Table 2 presents the results of the relationship between the protective measures and signs and symptoms variables, revealing that there is no statistical significance ($p < 0.001$) between the two variables, that is, the use of protective measures does not interfere with the manifestation of signs and symptoms.

DISCUSSION

The present study shows statistical significance for the development of signs and symptoms related to occupational exposure to surgical smoke in the integumentary and nervous systems, as shown in Table 1.

The literature brings a survey carried out in the surgical center with nurses and doctors in Turkey, where signs and symptoms were identified in nurses and doctors after exposure to surgical smoke: 61.9% had headaches, 29.5% irritability, 32.4% dizziness, 54.3% watery eyes, 41% coughing, 43.8% sensation of a foreign body in the throat, 44.8% sneezing, and 29.5% rhinitis¹².

Another survey, carried out in Mexico, identified that medical residents also presented signs and symptoms after occupational exposure to surgical smoke, such as a sensation of a foreign body in the throat (58.0%), burning in the pharynx (22.0%), and nasal congestion (2.0%)¹³.

In response to exposure to surgical smoke, a study was carried out whose objective was to evaluate the chemical composition of the surgical smoke produced during the loop electro-surgical excision procedure in the treatment of cervical intraepithelial neoplasia, and found an increase in the concentration of chemical compounds, such as carbon dioxide and formaldehyde, in surgical smoke¹⁴, which are responsible for respiratory discomfort, visual disturbances, tremors, loss of consciousness¹⁵, eye irritation, nausea, vomiting, headache, weakness, edema, dizziness, fatigue, and chest tightness¹⁶. It is believed that, in the long term, the chemical compound

Table 1. Prevalence of the intensity (low, moderate or high) of signs and symptoms related to exposure to surgical smoke, in health workers at the institutions participating in the study. Brazil, 2021.

System	Institution	Low (%)	Moderate (%)	High (%)	p-value
Respiratory	I	n=33 (21.3)	n=1 (0.6)	n=0	0.27
	II	n=45 (23.2)	n=5 (3.2)	n=2 (3.2)	
	Total	n=78 (44.5)	n=6 (3.9)	n=2 (3.2)	
Ocular	I	n=37 (23.9)	n=28 (18.1)	n=2 (1.3)	0.62
	II	n=51 (32.9)	n=32 (20.6)	n=5 (3.2)	
	Total	n=88 (56.8)	n=60 (38.7)	n=7 (4.5)	
Digestive	I	n=63 (40.6)	n=4 (2.6)	n=0	0.08
	II	n=75 (48.4)	n=13 (8.4)	n=0	
	Total	n=89 (89.0)	n=17 (11.0)	n=0	
Musculoskeletal	I	n=66 (42.9)	n=1 (0.6)	n=0	0.11
	II	n=79 (51.3)	n=5 (3.2)	n=0	
	Total	n=145 (94.2)	n=6 (3.9)	n=0	
Integumentary	I	n=58 (37.4)	n=9 (5.8)	n=0	0.05
	II	n=72 (46.5)	n=9 (5.8)	n=7 (4.5)	
	Total	n=130 (83.9)	n=18 (11.6)	n=7 (4.5)	
Nervous	I	n=41 (26.5)	n=26 (16.8)	n=0	0.01
	II	n=56 (36.1)	n=23 (14.8)	n=9 (5.8)	
	Total	n=97 (62.6)	n=49 (31.6)	n=9 (5.8)	

Table 2. Use of protective measures and the presence of signs and symptoms related to occupational exposure to surgical smoke in health workers. Brazil, 2021.

Protective measures		Signs and symptoms			p-value	Prevalence ratio
		No (%)	Yes (%)	Total (%)		
N-95	No	n=20 (12.9)	n=34 (21.9)	n=54 (34.8)	0.35	1.39
	Yes	n=30 (19.4)	n=71 (45.8)	n=101 (65.2)		
Surgical mask	No	n=6 (3.9)	n=48 (31.0)	n=54 (34.8)	0.62	0.77
	Yes	n=14 (9.0)	n=87 (56.1)	n=101 (65.2)		
Protective goggles	No	n=35 (22.6)	n=19 (12.3)	n=54 (34.8)	0.25	1.48
	Yes	n=56 (36.1)	n=45 (29.0)	n=101 (65.2)		
Smoke aspirator	No	n=51 (32.9)	n=3 (1.9)	n=54 (34.8)	0.42	0.52
	Yes	n=98 (63.2)	n=3 (1.9)	n=101 (65.2)		

formaldehyde can be carcinogenic, and cause leukemia and fetal malformations¹⁷.

Regarding the signs and symptoms related to the respiratory system, there is the question of the size of the particles present in surgical smoke. The smaller the particle, the greater their penetration power in the pulmonary alveoli. Particles with diameters smaller than 10 μm affect the

respiratory tract, particles smaller than 2.5 μm reach the pulmonary alveoli; particles smaller than 0.01 μm are characterized as ultrafine particles (UFP), with a deeper penetration power in the respiratory system, leading to greater impairment of this system^{13,18}.

The ultrafine particles present in surgical smoke are also responsible for reaching the alveolar region of the lung and causing lung

inflammation or disease, being composed of chemical products and pollutants that cause irritation in the eyes and lungs¹⁹.

A study proved that there is a difference in the concentration and size distribution of the particles produced during the use of an electric scalpel. As examples, the liver, when cauterized, produces a large amount of particles; the renal cortex, the renal pelvis, and the muscles, when cauterized, produce a medium amount of these particles; skin, gray matter, white matter, bronchi, and subcutaneous fat, when cauterized, produce small amounts of particles. However, the intensities are modified according to the worker's exposure time and the surgical smoke²⁰. It is necessary to take into account the sensitivity of each individual in presenting the signs and symptoms related to this occupational exposure.

According to the scale used and the intensity of signs and symptoms, it is understood that workers exposed with greater intensity of signs and symptoms will need specialized care to verify the development of diseases linked to this type of occupational exposure. But, in addition to intensity, the fact of presenting signs and symptoms alerts to what these workers will still be exposed to for a long time at work and that the need for differentiated care is urgent.

It should also be noted that there is no safe exposure to the particulate compounds present in surgical smoke, as they are carcinogenic and mutagenic, harmful to the health of workers²¹.

The use of individual protection measures by workers does not directly interfere with the manifestations of signs and symptoms, corroborating the recommendations of international organizations, which guide the use of a set of protection measures, including an exhaust fan in the operating room, surgical aspirators, and personal protective equipment (PPE).

According to the recommendation of an international organization, in order to reduce exposure to surgical smoke, a set of protective measures is necessary, namely: PPE, such as the N-95 or PFF2 type, smoke exhaust fans in the operating rooms¹⁰, as well as safety goggles.

Currently, surgical masks are the most used in SC, as they only capture particles of approximately 5 mm or more in size, but do not provide adequate protection in the inhalation of surgical smoke⁵. However, high filtration masks, such as the N-95 or PFF2, are recommended for protection against the harmful effects of surgical smoke⁵, as they filter against volatile molecules present in surgical smoke, and their use can be adopted by the whole team inside the operating room to avoid the risk of inhaling chemical products during exposure to electric scalpel smoke²². Therefore, studies suggest the use of high-efficiency particulate air filter masks to reduce exposure to surgical smoke²³.

In this sense, a study that uses a questionnaire answered by the participants as a data collection method has limitations related to the answers, which may not be as reliable. Therefore, one must consider this uncontrolled variable in this type of methodology. In addition to the fact that there was no statistical significance related to all the human systems evaluated, which may be related to the responses presented, as the respondents stated that they use protective glasses, but what is actually found in everyday life is the use of glasses for vision correction, and the SC at these institutions do not have a surgical smoke aspirator in the operating rooms.

It is also noteworthy that the signs and symptoms related to exposure to surgical smoke are common in the general population, which perhaps may not have been awakened in the research participants in relation to occupational risk.

Even with the aforementioned limitations and doubts, the present study advances in this innovative subject, which is a matter of concern for entities and managers, especially if the prevalent and intense signs and symptoms related to the pulmonary system of the research participants are confirmed.

The study also makes room for the need to develop new PPE, longitudinal studies that present a survival curve for these exposed individuals, in addition to different protocols for those exposed, as well as laws that establish the need for specific care for these workers.

CONCLUSION

The present study showed the prevalence and intensity of signs and symptoms related to occupational exposure to surgical smoke in the integumentary and nervous systems of health workers. It was found that the protective measures used alone are not protective factors for workers exposed to surgical smoke. Therefore, protective measures aimed at reducing the risk of exposure to surgical smoke should be used together.

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CONFLICT OF INTERESTS

The authors declare there is no conflict of interests.

AUTHORS' CONTRIBUTION

AAB: Project management, Formal analysis, Conceptualization, Data curation, Investigation, Methodology, Resources, Writing — original draft,

Writing — review & editing. HFL: Formal analysis, Conceptualization, Data curation, Investigation, Methodology, Writing — original draft. BCL: Methodology. MDC: Methodology. AFR: Methodology, Results. RPR: Supervision, Validation, Visualization.

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