

Relative risk and signs and symptoms of doctors exposed to surgical smoke: cohort study



Risco relativo e sinais e sintomas de médicos expostos à Fumaça Cirúrgica: Estudo de Coorte

Riesgo relativo y signos y síntomas de médicos expuestos al humo quirúrgico: estudio de cohorte

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ABSTRACT

Objective: To determine the relative risk and time to development of signs and symptoms related to exposure to surgical smoke in resident physicians.

Method: Prospective cohort, with 55 resident physicians exposed to surgical smoke and 45 unexposed. Collection took place in two hospital institutions in southern Brazil, in eight moments, from March 2018 to February 2020, using a form containing sociodemographic and labor information, signs, symptoms and self-reported preventive measures, conducted by trained researchers, who followed the participants throughout the process. Descriptive statistics, Chi-square, COX regression and Kaplan-Meier were used to analyze association, risk and time of onset of signs and symptoms.

Results: Exposed residents were 1.5 times more likely to develop signs and symptoms (95% CI: 0.99-2.42; $p=0.05$). The most common respiratory and eye symptoms were the sensation of a foreign body in the throat (HR: 3.86; $p<0.001$), burning sensation in the pharynx (HR: 2.49; $p=0.02$), eye irritation (HR: 3.43; $p<0.001$) and tearing (HR: 4.95; $p<0.001$). The median time for symptom development was 16 months (95% IQR: 14.8-17.1).

Conclusion: Residents exposed to surgical smoke are at greater risk of developing occupational symptoms, with an average time of 16 months for their onset.

Descriptors: Nursing; Signs and symptoms; Inhalation Exposure; Occupational exposure; Occupational Health.

RESUMO

Objetivo: Determinar o risco relativo e o tempo para o desenvolvimento de sinais e sintomas relacionados à exposição à fumaça cirúrgica em médicos residentes.

Método: Coorte prospectiva, com 55 médicos residentes expostos à fumaça cirúrgica e 45 não expostos. A coleta ocorreu em duas instituições hospitalares do Sul do Brasil, em oito momentos, de março de 2018 a fevereiro de 2020, utilizando-se um formulário contendo informações sociodemográficas, laborais, sinais, sintomas e medidas preventivas autorreferidas, sendo conduzido por pesquisadores capacitados, que acompanharam os participantes durante todo o processo. Foram utilizadas estatísticas descritivas, Qui-quadrado, regressão de COX e Kaplan-Meier para análise de associação, risco e tempo de aparecimento dos sinais e sintomas.

Resultados: Residentes expostos apresentaram 1,5 vezes mais risco de desenvolver sinais e sintomas (IC 95%: 0,99-2,42; $p=0,05$). Os sintomas respiratórios e oculares mais incidentes foram sensação de corpo estranho na garganta (HR: 3,86; $p<0,001$), ardência de faringe (HR: 2,49; $p=0,02$), irritação dos olhos (HR: 3,43; $p<0,001$) e lacrimejamento (HR: 4,95; $p<0,001$). O tempo mediano para o desenvolvimento de sintomas foi de 16 meses (IQ 95%: 14,8-17,1).

Conclusão: Residentes expostos à fumaça cirúrgica têm maior risco de desenvolver sintomas ocupacionais, com tempo médio de 16 meses para seu aparecimento.

Descritores: Enfermagem; Sinais e Sintomas; Exposição por Inalação; Exposição Ocupacional; Saúde Ocupacional.

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RESUMEN

Objetivo: Determinar el riesgo relativo y el tiempo de desarrollo de signos y síntomas relacionados con la exposición al humo quirúrgico en médicos residentes.

Método: Cohorte prospectiva, con 55 médicos residentes expuestos al humo quirúrgico y 45 no expuestos. La recolección se realizó en dos instituciones hospitalarias del sur de Brasil, en ocho momentos, de marzo de 2018 a febrero de 2020, mediante un formulario que contenía información sociodemográfica, laboral, signos, síntomas y medidas preventivas autoreportadas, realizado por investigadores capacitados, quienes acompañaron a los participantes durante todo el proceso. Se utilizó estadística descriptiva, Chi-cuadrado, regresión COX y Kaplan-Meier para analizar asociación, riesgo y tiempo de aparición de signos y síntomas.

Resultados: Los residentes expuestos tuvieron 1,5 veces más probabilidades de desarrollar signos y síntomas (IC 95%: 0,99-2,42; $p=0,05$). Los síntomas respiratorios y oculares más comunes fueron sensación de cuerpo extraño en la garganta (HR: 3,86; $p<0,001$), ardor en la faringe (HR: 2,49; $p=0,02$), irritación ocular (HR: 3,43; $p<0,001$) y lagrimeo (HR: 4,95; $p<0,001$). La mediana de tiempo de desarrollo de los síntomas fue de 16 meses (95% IQR: 14,8-17,1).

Conclusión: Los residentes expuestos al humo quirúrgico tienen mayor riesgo de desarrollar síntomas ocupacionales, con un tiempo promedio de aparición de 16 meses.

Descriptores: Enfermería; Signos y Síntomas; Exposición por Inhalación; Exposición Profesional; Salud Laboral.

■ INTRODUCTION

Healthcare workers may be exposed to several risks during their work activities. Among these, exposure to surgical smoke stands out, an occupational pollutant present in the air of operating rooms, which can cause signs and symptoms related to the nervous, respiratory, integumentary, cardiovascular, vestibular, gastrointestinal and ophthalmological systems⁽¹⁻³⁾

This smoke is produced during the use of electrocautery, equipment used in surgical procedures to reduce surgery time and cauterize blood vessels⁽²⁾. This pollutant is divided into two phases: particulate and gaseous, and is composed of blood, small particles, biological and chemical compounds⁽⁴⁾. In addition to the signs and symptoms presented by exposed workers, the composition of chemical substances in surgical smoke causes damage to the upper respiratory tract of individuals who inhale it that is sometimes irreparable⁽⁵⁾.

Such damages may be related to the chemical composition of surgical smoke, Polycyclic Aromatic Hydrocarbons (PAH), including naphthalene and phenanthrene, Volatile Organic Compounds (VOC), such as benzene and Carbon Monoxide⁽⁶⁻¹⁰⁾. The composition of surgical smoke may vary depending on the type of energy dispersed by the device, type of tissue treated and the duration of surgery⁽¹¹⁾.

Studies indicate that the risk of damage to the nasal mucosa, such as hyperplasia and metaplasia, in medical residents exposed to surgical smoke is 13.8 times greater than in non-exposed residents⁽¹²⁾. Furthermore,

the adoption of preventive measures to minimize the risks of this exposure is recommended. Among these, the use of local smoke extraction equipment or vacuum pumps with filters to suck the smoke produced at the source, the use of N95/PFF2 respirators, and adequate ventilation inside the surgical rooms, as well as personal protective glasses stand out⁽¹³⁻¹⁷⁾.

The damage caused by surgical smoke occurs cumulatively, that is, the longer the exposure time, the greater the risk of health impairment⁽⁸⁾. However, the signs and symptoms reported may be suggestive of other diseases, in addition to having a variable period to manifest, depending on the sensitivity of each exposed worker^(1,2).

Since the exposure time required for the development of signs and symptoms and, consequently, diseases associated with such exposure has not yet been defined, continuous monitoring of exposed workers is necessary. This will make it possible to determine when and how these workers should be monitored, preventing the development of occupational diseases⁽¹⁸⁾.

Although this study focused on resident physicians, other health professionals in the surgical team, such as nurses, nursing technicians, and surgical scrub nurses, are also exposed to surgical smoke and face the same occupational risks⁽¹⁾. Perioperative nurses, for example, play an essential role in surgical care and are frequently exposed to this pollutant. Therefore, including these professionals in the discussion broadens the understanding of the impacts of exposure and reinforces the need for more comprehensive preventive measures⁽¹⁸⁾.

Furthermore, Occupational Health Nurses play a fundamental role in implementing and monitoring preventive measures against exposure to surgical smoke. Occupational health nurses are essential for monitoring the health of exposed workers, and can perform clinical monitoring of these professionals, in addition to training teams on the risks involved. They also contribute to the development and implementation of strategies that minimize cumulative damage, such as the appropriate use of exhaust systems and Personal Protective Equipment (PPE), ensuring occupational safety in surgical rooms⁽¹⁹⁻²¹⁾.

Based on the above, the present study sought to answer the following questions: do resident physicians exposed to surgical smoke have a higher risk of developing signs and symptoms compared to non-exposed resident physicians? What is the time of exposure necessary for the development of signs and symptoms related to occupational exposure to surgical smoke?

Thus, the aim was to determine the relative risk and time for the development of signs and symptoms related to exposure to surgical smoke in resident physicians.

■ METHOD

Prospective cohort study conducted in two hospitals in southern Brazil that provide medium and high complexity care. Institution I is a public hospital linked to a state university, a reference for several medical specialties, has 329 inpatient beds and performs an average of 18 surgeries per day. It has a total of 207 residents divided into clinical, surgical and anesthesiology residencies.

Institution II is a tertiary-level philanthropic hospital, a reference center for cancer treatment in the region, with 335 beds and performing an average of 19 surgeries per day. It has a total of 65 residents divided into clinical, surgical and anesthesiology residencies.

The study population consisted of resident physicians who met the inclusion criteria, distributed into two distinct groups: those exposed and those not exposed (control group) to surgical smoke.

The inclusion criteria for the group exposed to surgical smoke were: resident physicians who started their activities in 2018 and were enrolled in specialties that perform procedures using electrocautery, therefore, directly exposed to surgical smoke during

anesthetic-surgical procedures. The specialties considered were: general surgery, vascular surgery, urology, orthopedics, gynecology, obstetrics, pediatric surgery, otorhinolaryngology, neurosurgery, and dermatology. In addition, as they remained in the operating room throughout the procedure, anesthesiology residents were also included in this group. Pediatrics and neonatology residents were considered exposed, because they were responsible for receiving newborns during cesarean sections, and were also subject to inhalation of surgical smoke.

The inclusion criteria for the non-exposed group (control group) were resident physicians who started their activities in 2018 and worked exclusively in clinical and outpatient specialties that did not perform surgical procedures using electrocautery. Since these specialties do not involve the use of this equipment in their practice, these residents were not exposed to surgical smoke inhalation.

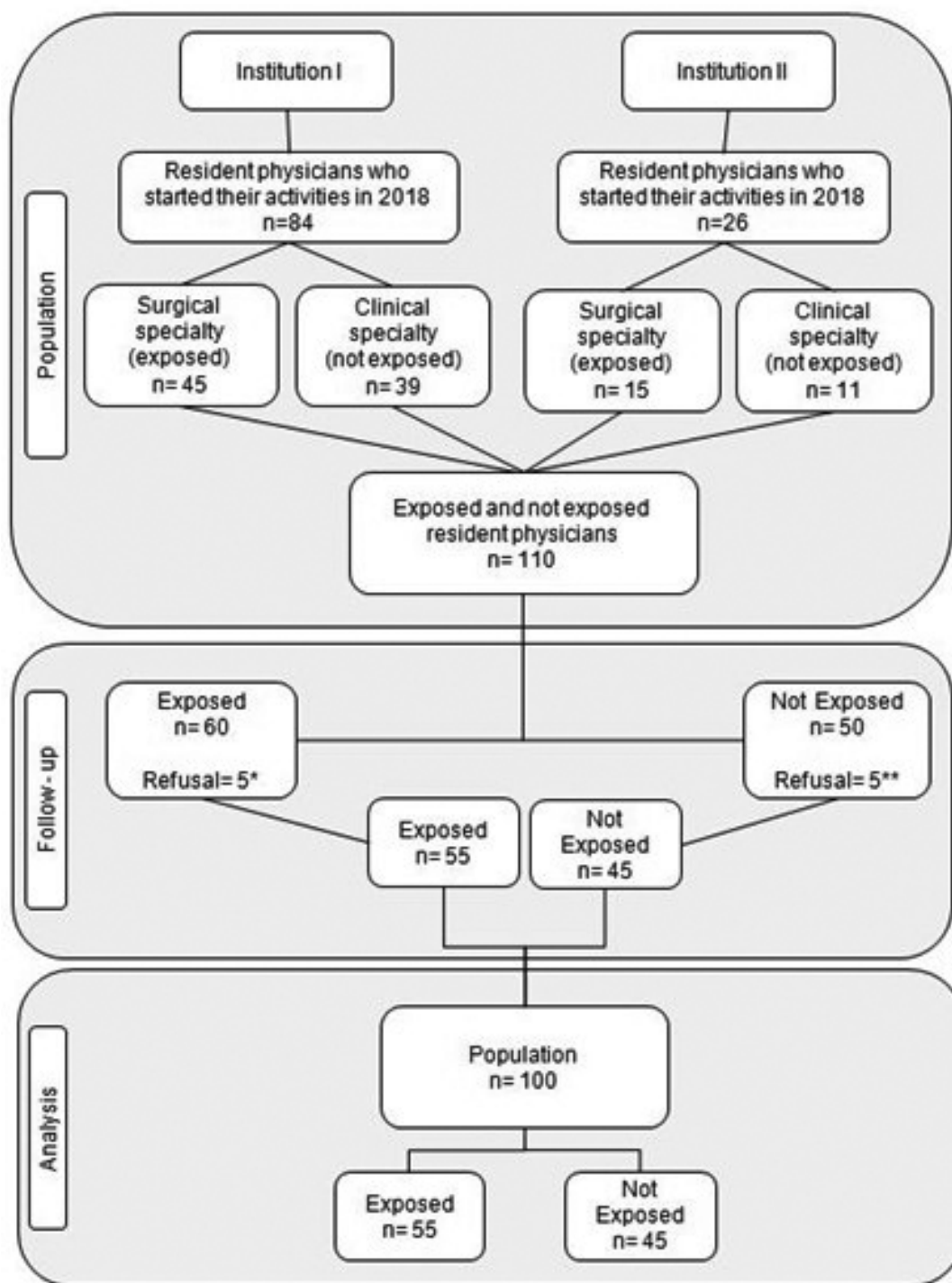
The exclusion criteria for both groups (exposed and unexposed) were ophthalmology residents who did not use electrocautery in their surgical activities.

The sample size calculation for data collection was performed using the EpiInfo program, based on a previously conducted study with the same cohort methodological design and a population identical to that of this study⁽¹⁸⁾. The significance level adopted was 5% and the test power was 80%, performed using the Bioestat software, version 5.3. Therefore, the sample size calculation determined 39 medical residents in each group (exposed and unexposed).

The decision was made to follow over the time all eligible resident physicians, given the 20% loss rate, common in a prospective cohort studies, and the fact that the population eligible for the study was larger than the sample size calculation. Figure 1 shows the data on the inclusion and follow-up of the resident physicians in the exposed group and the unexposed group (control) in this study.

Data collection was performed in eight moments, starting with Time 0 (T0) in March 2018, which was the beginning of the residency, and the end of the follow-up was at Time 7 (T7) in February 2020, when the residents finished their medical residency. In this way, it was possible to determine the time for the development of signs and symptoms related to

Figure 1. Scheme for inclusion and monitoring of resident physicians in groups exposed and not exposed to surgical smoke. Brazil, 2018-2020.



Source: Research data, 2020.

*Excluded in the stage of follow-up among the exposed group: Neonatology (n=1); General surgery (n=1); Pediatrics (n=1); General surgery (n=2); **Excluded in the follow-up stage among the unexposed group: Cardiology (n=1); Neurology (n=1); Internal medicine (n=3).

exposure to surgical smoke. The collection times were as follows: Time Zero (T0) March/2018, Time One (T1) May/2018, Time Two (T2) August/2018, Time Three (T3) November/2018, Time Four (T4) February/2019, Time Five (T5) May/2019, Time Six (T6) August/2019 and Time Seven (T7) February/2020. T0 was not considered follow-up, but rather as the baseline of the research, configuring a follow-up period of 21 months for the prospective cohort.

The interval between each data collection was three months, as evidenced by a previous study carried out by the researchers⁽¹⁸⁾, which demonstrated that the quarterly frequency was sufficient to verify the development of signs and symptoms, without the need for monthly monitoring.

Data collection was performed in a standardized manner by a team of researchers and undergraduate students, all of whom were properly trained to ensure uniformity in the process. Each collection was supervised by the lead researcher to ensure adherence to the protocol and avoid the loss of essential information. To maintain reproducibility, each participant answered a single standardized form, which was completed sequentially by the researchers during predetermined times.

The forms used were evaluated by five judges, with expertise in occupational health and/or surgical centers, in order to analyze the clarity, understanding of the items contained in the forms, form of presentation of the items, scope and representativeness of the content, to achieve the objective defined in this research⁽¹⁸⁾.

The judges were invited to participate in the evaluation of the data collection form through a summary containing the presentation of the study, the objectives, the methodology and what the evaluation should be. The Free and Informed Consent Form (FICF) was also sent to them so that they could accept to participate in the evaluation of the form. All suggestions made were considered by the researchers.

The form used for data collection consisted of sociodemographic characteristics, lifestyle habits and pre-existing diseases of the residents: age (years), year of graduation, presence of any chronic disease, smoking (dichotomous), previous specialization or residency in which the resident used electrocautery, length of this specialization (years) and current specialty. These data were collected from the exposed group and the unexposed group (control).

A specific data collection form was also used for the exposed group. At T0, participants were asked about: times per week they were present in the surgical center (morning, afternoon, and evening), hours per week performing surgical procedures, and the number of surgeries they participated in in the last month, since T0 was the first month of residency and all items were self-reported. In the other collections (T1 to T7), exposed residents were asked about the approximate number of surgical procedures performed in the last three months.

The form was used to collect signs and symptoms related to inhalation of surgical smoke from the exposed and non-exposed (control) groups, namely: sensation of a foreign body in the throat, burning sensation in the pharynx, nausea, nasal congestion, headache, eye irritation, irritation of other mucous membranes such as the mouth and nose, weakness, dizziness, nasopharyngeal injuries, vomiting, tearing and sneezing. In addition, all participants were asked about other signs or symptoms that were not anticipated in the data collection form, which may be included in the form in future studies.

The same form included preventive measures recommended in the literature for the use of electrocautery: use of a surgical mask, use of an N95/PFF2 respirator mask, use of protective glasses, and use of a specific vacuum cleaner for surgical smoke. These questions were applied to the group exposed to surgical smoke.

All questions about signs and symptoms and the use of preventive measures to protect against surgical smoke were answered by residents in a dichotomous manner, that is, by answering yes or no.

Data analysis was performed in Statistical Package of Social Sciences (SPSS), version 20.0. In descriptive statistics, absolute and relative frequencies and measures of central position and dispersion were used.

Chi-Square test was performed to analyze the possible association of dichotomous nominal variables. To evaluate exposure to surgical smoke and age between groups, the Mann-Whitney U test was used. For the overall risk analysis of the appearance of signs and symptoms in exposed and unexposed resident physicians, COX Regression was used. Confounding variables were adjusted, such as: number of surgeries performed in the month, time of stay in the surgical center, use of protective equipment and pre-existing medical history. A significance level of 5% ($p < 0.05$) was considered. Kaplan-Meier Survival Analysis was

performed to verify the time of onset of signs and symptoms in the exposed and unexposed groups.

The Hazard Ratio (HR), with respective 95% confidence interval, was calculated as a measure of effect. For the interpretation of HR, the following was adopted: equal to 1, absence of association between exposure and outcome; greater than 1, exposure was a risk factor for the outcome; and less than 1, exposure was a protective factor for the outcome⁽²²⁾.

The study met the ethical criteria for research involving human beings. Approved under the Certificate of Presentation for Ethical Appreciation (CAAE) number of institution I: 46229915.0.0000.5231 and CAAE number of institution II: 46229915.0.3001.0099.

■ RESULTS

One hundred resident physicians who were eligible for this research participated in this study, of which 55 (55%) resident physicians comprised the group exposed to surgical smoke and 45 (45%) resident physicians comprised the group not exposed (control) to surgical smoke.

Table 1 presents the sociodemographic characteristics of residents exposed and not exposed (control) to surgical smoke, lifestyle habits and pre-existing diseases. After performing the chi-square test, none of the variables showed an association with the appearance of signs and symptoms.

Some chronic diseases were reported by resident physicians such as: allergic rhinitis, hypothyroidism, migraine, asthma, myasthenia, systemic arterial hypertension (SAH), fibromyalgia and irritable bowel syndrome.

Table 2 presents the Kaplan-Meier survival table, which shows the probability of residents exposed and not exposed to surgical smoke not to present signs and symptoms during the follow-up period and the risk rate with the time of exposure. Therefore, as the months of follow-up pass, the survival rate decreases, while the risk rate increases.

Regarding signs and symptoms, 87.2% (n=48) of resident physicians exposed to surgical smoke reported the presence of signs and symptoms and 12.8% (n=7) reported the absence of these. Regarding the group not exposed to surgical smoke, it was found that 86.6% (n=39) presented some signs or symptoms and 13.4% did not.

Table 1. Sociodemographic characteristics, lifestyle habits and pre-existing diseases of resident physicians exposed and not exposed to surgical smoke (n=100). Londrina, PR, Brazil, 2020.

Features	Residents exposed to surgical smoke (n=55)	Residents not exposed to surgical smoke (n=45)	p-value *
Age (Median-IQ)	27 (24-30)	27 (24-32)	0.928**
Sex			
Women	30 (54.5%)	17 (37.8%)	0.09
Men	25 (45.5%)	28 (62.2%)	
Smoking			
No	52 (94.5%)	43 (95.6%)	0.81
Yes	3 (5.5%)	2 (4.4%)	
Chronic disease			
No	36 (65.5%)	22 (48.9%)	0.09
Yes	19 (34.5%)	23 (51.1%)	

Source: Research data, 2020.

- Median (p25-p75)

Chi-square test

**Mann-Whitney U- test

Table 2. Survival table of resident physicians exposed and not exposed to surgical smoke. Brazil, 2020.

Exposure to surgical smoke	Times of follow-up	Nº. of Individuals	Nº. of Censored data	Nº. Exposed to the risk	Nº. of individuals with signs and symptoms	Survival rate (%)	Risk rate(%)	EP* Risk rate(%)
No exposed	T0	45	1	4 4	–	100	–	–
	T1	44	–	4 4	1	98	1	1
	T2	43	–	4 3	3	93	2	1
	T3	40	1	3 9	5	87	5	2
	T4	34	1	3 3	5	85	5	2
	T5	28	2	2 7	3	89	4	2
	T6	23	1	2 2	8	64	14	5
	T7	14	3	1 2	11	12	52	10

Table 2. Cont.

Exposure to surgical smoke	Times of follow-up	Nº. of Individuals	Nº. of Censored data	Nº. Exposed to the risk	Nº. of individuals with signs and symptoms	Survival rate (%)	Risk rate(%)	EP* Risk rate(%)
Exposed	T0	55	–	5 5	3	95	2	1
	T1	52	2	5 1	2	96	1	1
	T2	48	2	4 7	3	94	2	1
	T3	43	2	4 2	3	93	2	1
	T4	38	2	3 7	8	78	8	3
	T5	28	2	2 7	7	74	10	4
	T6	19	–	1 9	14	26	39	8
	T7	5	–	5	5	–	67	–

Source: Research data, 2020.
- Numerical data equal to zero, not resulting from rounding
*EP – Standard error

The incidence of signs and symptoms related to exposure to surgical smoke is shown in Table 3. Those exposed have a higher incidence of signs and symptoms such as a sensation of a foreign body in the throat, burning sensation in the pharynx, headache, eye irritation, irritation of other mucous membranes such as the mouth and nose, tearing and nasopharyngeal injuries compared to those not exposed.

In the global analysis of the time for the development of signs and symptoms, it was found that the median in the exposed group was approximately 16 months (95% IIQ: 14.8-17.1).

In the global analysis comparing the appearance of signs and symptoms when exposed to surgical smoke, it was found that resident physicians exposed to surgical

smoke were 1.5 times more likely to have signs and symptoms than non-exposed resident physicians (control) (HR: 1.5; 95% CI: 0.99-2.42; $p=0.05$). However, as the confidence interval includes the null value (1.0), the result should be interpreted with caution regarding statistical significance.

Figure 2 shows the survival function by sign and symptom. It can be seen that the appearance of signs and symptoms is greater in the exposed group compared to the non-exposed group for sensation of foreign body in the throat (HR: 3.86; 95% CI: 1.46-11.85; $p<0.001$), burning sensation in the pharynx (HR: 2.49; 95% CI: 1.13-5.46; $p=0.02$), eye irritation (HR: 3.43; 95% CI: 1.75-6.74; $p<0.001$) and tearing (HR: 4.95; 95% CI: 2.36-10.39; $p<0.001$).

Table 3. Incidence of signs and symptoms in resident physicians exposed and not exposed to surgical smoke and survival time (n = 100). Brazil, 2020.

Signs and symptoms	Resident physicians exposed to surgical smoke	Resident physicians not exposed to surgical smoke	Median survival time* (months) (IIQ 95%)
	N (%)	N (%)	
Feeling of foreign body in the throat	12 (22.2)	4 (8.9)	22.0 (19.8 - 24.1)
Burning sensation in the pharynx	19 (34.5)	10 (22.2)	22.0 (17.7 - 26.2)
Nausea	9 (16.4)	8 (17.8)	22.0 (18.5 - 25.4)
Vomiting	1 (1.8)	4 (8.9)	–
Nasal congestion	28 (53.8)	28 (63.6)	19.0 (17.3 - 20.6)
Headache	28 (53.8)	21 (47.7)	19.0 (17.8 - 20.1)
Eye irritation	30 (54.5)	13 (28.9)	19.0 (17.7 - 20.2)
Irritation of other mucous membranes**	16 (29.1)	11 (24.4)	22.0 (18.4 - 25.5)

Table 3. Cont.

Signs and symptoms	Resident physicians exposed to surgical smoke	Resident physicians not exposed to surgical smoke	Median survival time* (months) (IIQ 95%)
	N (%)	N (%)	
Sneezing	21 (38.2)	27 (60)	19.0 (16.8 – 21.1)
Weakness	8 (14.5)	6 (13.3)	–
Dizziness	7 (12.7)	5 (11.1)	22.0 (-)
Tearing	27 (49.1)	8 (17.8)	19.0 (17.5 – 20.4)
Nasopharyngeal injuries	7 (12.7)	4 (8.9)	–

Source: Survey data, 2020.

*Kaplan-Meier survival analysis **mouth and nose // – Disappearance of symptoms during follow-up

Regarding the use of preventive measures, it was found that 66.3% of residents exposed to surgical smoke did not use a surgical mask, and were present in the surgical rooms without respiratory protection, and 96.4% did not use an N95 respirator. Only 1.8% had already used a specific aspirator for surgical smoke, and 83.9% did not use protective glasses. In addition, exposed residents reported during data collection that, when performing surgical procedures, they used their own glasses and not the protective glasses recognized as Personal Protective Equipment (PPE).

■ DISCUSSION

The participants exposed to surgical smoke were aged 28-40 years old. It should be considered that most of their lives will be exposed to this risk, since in addition to having six years of college, some residencies can last up to five more years so that these professionals become experts in what they set out to do. From then on, these doctors may be exposed to surgical smoke throughout their entire lives during their work activity.

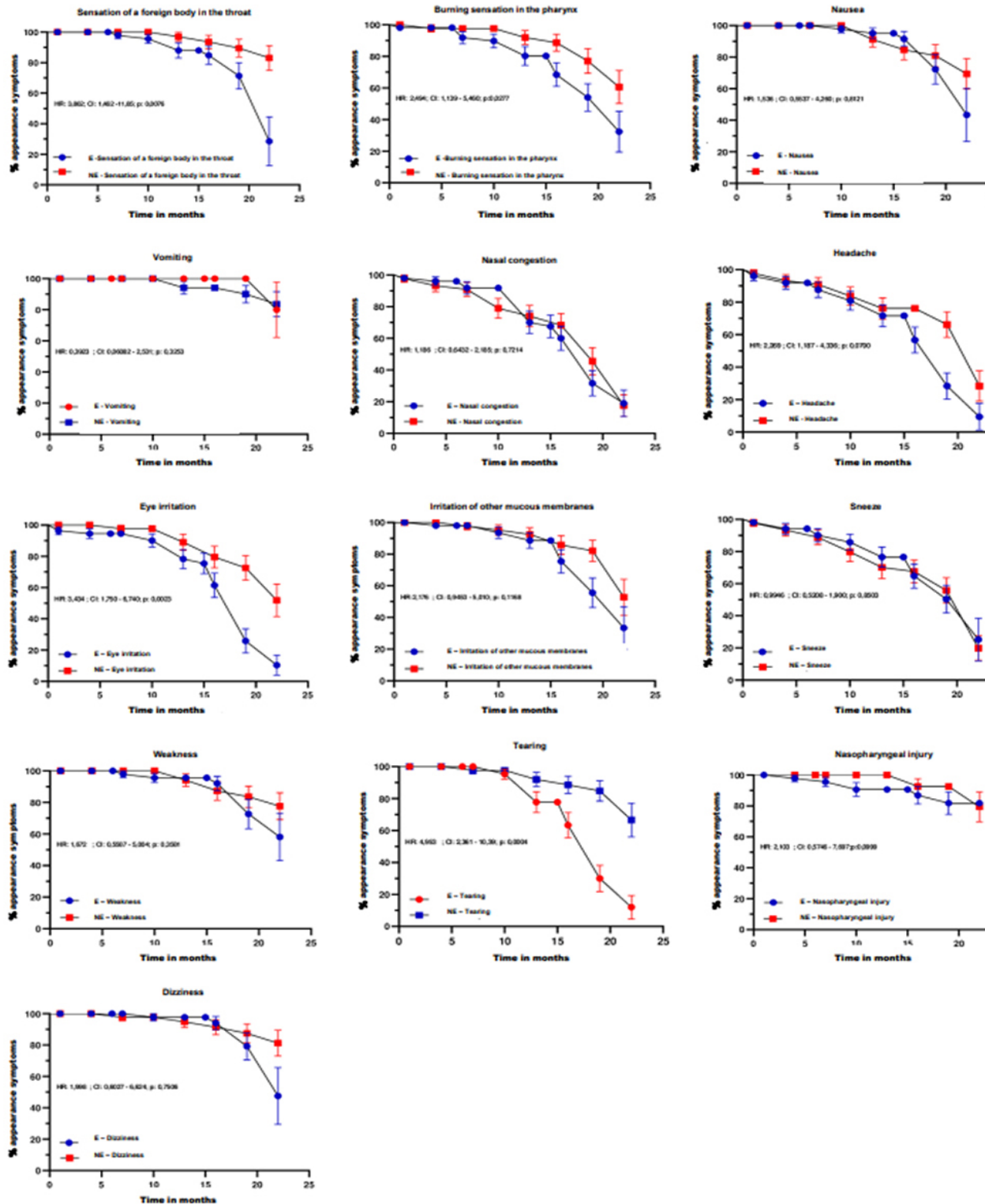
If these professionals work for 35 years, the risk of developing diseases related to exposure to surgical

smoke will be increased, since the deleterious effect on the exposed organism is cumulative⁽⁸⁾. In addition, resident physicians exposed to surgical smoke have a 1.5 times greater risk of presenting signs and symptoms over the time of exposure than non-exposed resident physicians, regardless of which sign and symptom is reported.

Although the association between exposure and the onset of symptoms is significant, it should be considered that signs and symptoms may be related to other health conditions, not necessarily surgical smoke.

Furthermore, the data suggest that the intensity of symptoms is more related to exposure to smoke than to its mere onset. In other words, it is not just the fact that symptoms appear that should be considered, but rather how severe the intensity of these symptoms can be in workers exposed to this agent. Working with the intensity of signs and symptoms is relevant, as it can more accurately reflect the negative impact of exposure over time, suggesting that, as exposure increases, there is a tendency for the intensity of symptoms to worsen, such as eye irritation, breathing difficulties, among others⁽¹⁾.

Figure 2. Survival function by sign and symptom in those exposed and not exposed to surgical smoke during the follow-up period (21 months). Brazil, 2020.



Source: Survey data, 2020.

HR: Hazard Ratio ; CI: 95% confidence interval; p<0.05; E: Exposed; NE: Not exposed.

In this study, exposed resident physicians had a 3.8 times greater risk of developing a foreign body sensation in the throat, a 2.4 times greater risk of burning sensation in the pharynx, a 3.4 times greater risk of developing eye irritation, and a 4.9 times greater risk of developing tearing, when compared to those not exposed.

The same occurred in another study with a longitudinal design, which determined that the risk of a resident physician exposed to surgical smoke experiencing a sensation of a foreign body in the throat is greater (13.8 times) than in those not exposed to this risk⁽¹²⁾. This is one of the reasons for concern, according to the Occupational Safety and Health Administration (OSHA), as approximately 500,000 workers are exposed to this occupational risk each year⁽¹³⁾.

The chemical composition of surgical smoke (xylene, phenol and benzene, acetaldehyde and polycyclic aromatic hydrocarbons such as naphthalene, formaldehyde, furfural and toluene) is responsible for the sensation of a foreign body in the throat or burning in the pharynx and eye irritation⁽²³⁾, which is in line with the results presented in this study.

Surgical smoke, when formed, contains particles that can cause lung irritation, both for the surgical team and for the exposed patient⁽²⁴⁾. Its particles are considered aerosols due to their size, which varies from 0.1 to 0.5 microns⁽²⁵⁾. Therefore, when inhaled, they can remain trapped in the respiratory tract and penetrate the alveoli⁽⁵⁾, causing pulmonary signs and symptoms.

Occupational health nurses play an essential role in promoting the health and safety of hospital workers, and are essential for epidemiological surveillance and the creation of safer work environments⁽²⁶⁾. In addition to providing direct care to workers, the work of these professionals involves continuous monitoring of respiratory, ophthalmological and cutaneous signs and symptoms, especially among those exposed to risk agents such as surgical smoke, chemicals, radiation and other contaminants present in the hospital environment. These risks can affect the health of workers silently and progressively, making the work of occupational health nurses important for the early detection of complications, preventing occupational diseases and promoting a healthier work environment^(20,21).

Furthermore, Occupational Health Nursing has a significant impact on the integration of the multidisciplinary team, collaborating with physicians, physiotherapists, psychologists and other health professionals in identifying conditions related to the work environment. This joint work is essential for the implementation of preventive and rehabilitative actions, in addition to the creation of occupational safety policies^(20,21).

Encouraging the appropriate use of Personal Protective Equipment (PPE), conducting periodic examinations and providing ongoing education to workers are essential to ensuring the health and well-being of all. This integrated approach strengthens the prevention of occupational risks, improves the quality of life of health professionals and contributes to a safer and more efficient hospital environment for the entire team^(19,20).

Furthermore, studies show that cauterization of some tissues generates more particulate matter than others, for example: the liver, which generates a large amount of particulate matter when subjected to electrocauterization⁽²⁷⁻²⁸⁾. Other tissues, such as skin, gray and white matter, subcutaneous tissue and lungs, generate a smaller amount of particulate matter⁽²⁷⁻²⁸⁾.

Therefore, when performing a surgical procedure on the liver, the exposed surgical team is at increased risk, even for those workers who are further away from the surgical field. And even for those organs that generate less particulate matter during cauterization, it should be noted that there is no safe occupational exposure when these chemical compounds are present⁽²⁹⁾. Therefore, there is a need for the correct use of PPE and other equipment suitable for worker protection, in addition to conducting more detailed longitudinal studies with greater control of the variables present in the occupational environment.

Regarding the use of PPE for this occupational exposure, surgical masks, commonly used in operating rooms during surgical procedures⁽³⁰⁾, have the main function of protecting the team from blood droplets and other secretions, in addition to protecting the patient's exposed cavity, sterile fields and instruments from microorganisms that the team may present⁽³¹⁾, especially when talking during the anesthetic-surgical procedure.

However, surgical masks are not effective in protecting the surgical team in the event of exposure to the aforementioned chemical compounds, as they do not have the capacity to filter small particles⁽²⁵⁾, as is the case with the compounds present in surgical smoke, and, furthermore, they do not fit correctly on the face, causing surgical smoke to easily penetrate the worker's respiratory area.

Therefore, the use of N95 and PFF2 respiratory masks is recommended as a preventive measure for this type of exposure⁽¹⁴⁾, which are capable of filtering up to 95% of the particles generated, such as aerosols, gases and smoke⁽³²⁻³³⁾.

This type of protective mask provides effective filtration for particles larger than 0.3 micron⁽²⁵⁾, that is, they cannot filter all the chemical compounds present in surgical smoke; they are smaller than the size of the particles filterable by the N95 mask^(14,25). Therefore, there is a need to build a respiratory mask that is effective for retaining the chemical compounds generated by surgical smoke and that is comfortable, in order to guarantee the safety and adherence of workers exposed to this PPE.

Regarding the use of goggles as PPE, there is no consensus in the literature on such use. However, it was found that when professionals do not use protective goggles, they show signs of eye irritation and tearing⁽¹⁻²⁾ with a 3.43 times greater risk of eye irritation and 4.95 times greater risk of tearing compared to those not exposed.

These results allow us to hypothesize that the use of protective eyewear (PPE) prevents contact of the ocular mucosa with surgical smoke, reducing direct exposure to the components present in surgical smoke.

There are also recommendations on the need for ventilation in operating rooms with air renewal⁽¹⁶⁾, in addition to the use of specific aspirators for surgical smoke with filtering of these chemical compounds⁽¹³⁾, which does not happen in most Brazilian hospital institutions.

As a limitation of the study, we can mention the lack of control of variables such as the concentration of surgical smoke during the moment of exposure and the exact time of exposure of residents to surgical smoke, in addition to the sample size, which does not

allow generalization of the results. In addition, the data collected were self-reported, which may generate information bias. It should also be considered that the signs and symptoms are not specific to this type of exposure and may be signs and symptoms caused by other diseases common to the population, corroborating new analyses of the intensity of signs and symptoms in health professionals exposed to surgical smoke.

Regarding the high rate of non-use of PPE in the exposed group, a behavioral bias is suggested, where symptoms may be related to the lack of individual protection, and not exclusively to exposure to surgical smoke.

However, this study contributes to scientific knowledge regarding the risks that surgical smoke can cause to the team exposed to it. It is possible to verify the incidence of signs and symptoms with statistical significance during the period in which medical residents were exposed to smoke, a result that has not been described in the literature. It also highlights how exposed residents may be more prone to developing signs and symptoms related to exposure to surgical smoke and, consequently, to developing diseases linked to this risk, in a silent way, such as alveolar congestion, pneumonia, bronchiolitis and changes in the respiratory tract.

■ CONCLUSION

The incidence of foreign body sensation in the throat, burning sensation in the pharynx, headache, eye irritation, irritation of other mucous membranes, tearing and nasopharyngeal injuries was higher in the exposed group when compared with the unexposed group. Furthermore, the time for the development of signs and symptoms in the exposed group was approximately 16 months after the start of occupational exposure.

A higher incidence of signs and symptoms was observed among resident physicians exposed to surgical smoke compared to those not exposed. The analysis performed using the survival test demonstrated the presence of risk associated with exposure. This finding highlights the importance of conducting new studies to estimate its magnitude more accurately and better understand the factors related to this outcome.

Furthermore, exposed resident physicians have a significantly higher risk of developing respiratory and ocular signs and symptoms: sensation of a foreign body in the throat, burning sensation in the pharynx, eye irritation and tearing.

Given the results found, it is important to consider the limitations of the study to avoid overestimating the results. Also, the importance of effective preventive measures for exposure to this occupational risk is highlighted, with emphasis on the role of nursing, which should be seen as essential in the implementation of these measures. It is the duty of researchers to invest in health technologies, especially in the development of PPE that favors continuous use, providing comfort and safety for workers exposed to these risks during their working lives.

Furthermore, it is essential to discuss the impact of these findings on occupational safety and labor legislation, especially regarding surgical smoke, a significant occupational risk. Thus, the NR 32 regulatory standard, focused on protection against chemical occupational risks to which health professionals are subject, is relevant, since the present study addresses the chemical risk of surgical smoke. The creation and implementation of appropriate institutional policies and regulations are essential for the protection of health workers.

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■ Availability of data and material

Access to the dataset may be granted upon request to the corresponding author.

■ Authors' Contribution

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