

## POLYCYCLIC AROMATIC HYDROCARBONS: CORRELATION BETWEEN THE TIME OF ELECTROCAUTERY USE AND SURGICAL TIME\*

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**ABSTRACT:** The objective was to identify concentrations of polycyclic aromatic hydrocarbons produced by electrocautery smoke in operating rooms, correlating these concentrations with time of electrocautery and surgical use. This is a cross-sectional and quantitative field study carried out in 50 gastrointestinal surgical procedures, between April and July 2015, in a university hospital in the state of Paraná. Hydrocarbons were collected using a suction pump and measurements were determined through liquid chromatography. These compounds were found to have an average of 0.0058 mg.m<sup>-3</sup> and a mean of 0.0049 mg.m<sup>-3</sup>. The mean surgical time and electrocautery use were 136 minutes and 220.5 seconds, respectively. The Spearman correlation test was -0.512 between concentration variables and surgical time, and -0.183 between the concentrations and electrocautery use. The conclusion was the presence of hydrocarbons and a low correlation between the production of these compounds and the electrocautery usage time.

**DESCRIPTORS:** Occupational exposure; Occupational air pollutants; Electrosurgery; Protective devices.

### HIDROCARBONETOS POLICÍCLICOS AROMÁTICOS: CORRELAÇÃO ENTRE TEMPO DE USO DO ELETROCAUTÉRIO E TEMPO CIRÚRGICO

**RESUMO:** Objetivou-se identificar concentrações de hidrocarbonetos policíclicos aromáticos provenientes da fumaça do eletrocautério nas salas operatórias, correlacionando estas concentrações com o tempo de uso do eletrocautério e cirúrgico. Trata-se de um estudo de campo, transversal e quantitativo, realizado em 50 atos cirúrgicos do aparelho digestivo, entre abril e julho de 2015, em hospital universitário no estado do Paraná. Foram coletados hidrocarbonetos por meio de uma bomba de sucção e determinados por cromatografia líquida. Estes compostos foram encontrados com média de 0,0058 mg.m<sup>-3</sup> e mediana de 0,0049 mg.m<sup>-3</sup>. O tempo médio cirúrgico e de uso do eletrocautério foram de 136 minutos e 220,5 segundos, respectivamente. O teste de correlação de Spearman foi de -0,512 entre as variáveis concentrações e tempo cirúrgico e de -0,183 entre as concentrações e tempo de uso do eletrocautério. Conclui-se que existem hidrocarbonetos e há baixa correlação entre a produção destes compostos e tempo de uso do eletrocautério.

**DESCRIÇÕES:** Exposição ocupacional; Poluentes ocupacionais do ar; Eletrocirurgia; Equipamentos de segurança.

### HIDROCARBUROS POLICÍCLICOS AROMÁTICOS: CORRELACIÓN ENTRE TIEMPO DE USO DEL ELECTROCAUTERIO Y TIEMPO QUIRÚRGICO

**RESUMEN:** Se objetivó identificar concentraciones de hidrocarburos policíclicos aromáticos derivados del humo del electrocauterio en quirófanos, correlacionando las concentraciones con el tiempo de uso del electrocauterio y quirúrgico. Estudio de campo, transversal, cuantitativo, realizado en 50 actos quirúrgicos del aparato digestivo, entre abril y julio de 2015, en hospital universitario del estado de Paraná. Fueron recolectados hidrocarburos mediante una bomba de succión, y determinados por cromatografía líquida. Los compuestos fueron encontrados con promedio de 0,0058 mg.m<sup>3</sup> y mediana de 0,0049 mg.m<sup>3</sup>. El tiempo promedio quirúrgico y de uso del electrocauterio fue de 136 minutos y 220,5 segundos respectivamente. El test de correlación de Spearman fue de -0,512 entre variables concentraciones y tiempo quirúrgico, y de -0,183 entre las concentraciones y tiempo de uso del electrocauterio. Se concluye en que existen hidrocarburos y hay baja correlación entre la producción de tales compuestos y tiempo de uso del electrocauterio.

**DESCRIPTORES:** Exposición Profesional; Contaminantes Ocupacionales del Aire; Electrocirugía; Equipos de Seguridad.

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## ● INTRODUCTION

The operating room (OR) may be considered a unique sector in relation to other hospital sectors, because it is a setting prone to several occupational risks for health workers. Among the risks present in the OR, there is the chemical risk characterized by the surgical smoke produced by electrocautery use.

Electrocautery applies electric current for the rupture and hemostasis of tissues in several surgical specialties. Among its advantages is the reduction of surgical time.<sup>(1)</sup>

However, among the disadvantages is that the use of the referenced device produces surgical smoke generated by heating the tissue and vaporization of the cellular components, causing a foul smell for the health team and reducing the visibility of videolaparoscopic surgeries.<sup>(2-4)</sup>

This surgical smoke is formed by water vapor and chemical compounds,<sup>(5-6)</sup> including polycyclic aromatic hydrocarbons (PAH) and carbon oxides.<sup>(5,7-8)</sup> There can also be the presence of microorganisms in the smoke, such as *Mycobacterium tuberculosis* and the human immunodeficiency virus (HIV), causing a still immeasurable risk of infection.<sup>(6,9)</sup> The referenced chemical substances may affect the respiratory system, causing a pharyngeal burning sensation and nasal congestion, and can even cause cancer.<sup>(1,10)</sup>

Among the compounds mentioned, attention is drawn to PAHs, which are organic compounds formed by aromatic rings, carbon, and hydrogen,<sup>(11)</sup> which, in addition to being carcinogens, can have effects on the skin, liver, and immune system.<sup>(10)</sup>

A U.S. agency stated that there is a lack of studies available on PAH effects on the human body based on specific concentration levels,<sup>(12)</sup> emphasizing the importance of conducting studies to correlate PAH concentrations with the effects of these concentrations on the human body.

The referenced compound was found in electrocautery smoke, as international studies have shown.<sup>(5,13-15)</sup> However, the studies are still limited, especially national ones addressing the presence of chemical compounds in surgical smoke,<sup>(16)</sup> in addition to those that correlate time of electrocautery use and surgical time.

Therefore, studies confirm that, while using electrocautery, protective measures are crucial to minimize occupational risks and to protect the intraoperative team that is exposed to surgical smoke on a daily basis. The OR must have local smoke extraction systems near the emission area,<sup>(17)</sup> effective ventilation systems,<sup>(18)</sup> including individual protection equipment for the intraoperative team, such as N-95 respirators,<sup>(17,19)</sup> and safety goggles.<sup>(18)</sup>

However, there is a lack of international health occupational legislation and recommendations to regulate the use of protective measures in surgical procedures while using electrocautery in the OR, such as those of the National Institute for Occupational Safety and Health, the Association of Perioperative Registered Nurses, and New South Wales (Australia),<sup>(17-19)</sup> wherein the use of these measures is not clear regarding the type of surgery (open or videolaparoscopic), surgical specialty, surgical time, and time of electrocautery use. In addition, these international legislation/recommendations do not apply to Brazil.

As described above and analyzed according to the 2030 Agenda for Sustainable Development Goals set out by the UN. One such goal is to protect workers and to promote a safe and protective workplace environment for all employees.<sup>(20)</sup> This goal and the lack of studies correlating PAH, surgical time, and time of electrocautery use served the purpose for this study of answering the following questions: Is there PAH in the air of operating rooms? Do PAH concentrations increase proportionally with electrocautery use and surgical time?

Based on the above considerations, effort was made to identify PAH concentrations derived from electrocautery smoke in the operating rooms and correlate the concentrations of these compounds with the time of electrocautery use and surgical time.

## ● METHOD

This was an exploratory, cross-sectional field research study with a quantitative approach carried out in the OR of a major university hospital located in the state of Paraná, Brazil. The referenced OR relies on seven operating rooms, in which nearly 700 elective and emergency surgeries are performed each month. Staff includes 262 health workers and *lato sensu* post-graduate students.

For this research, gastrointestinal surgeries were chosen, because they take place on a daily basis, with an average of two surgeries using electrocautery. This surgical specialty is carried out during an average of 30 surgeries monthly.

The inclusion criteria were elective or emergency gastrointestinal surgeries using electrocautery during the surgical procedure. Therefore, the purposive sampling of this study consisted of 50 surgeries. The exclusion criterion was emergency surgery, because of the limitation in setting up the devices in a timely manner for the beginning of the surgery and data collection.

The period for data collection took place from April to July, 2015, during morning, afternoon, and evening shifts, applying a data collection form that included the following variables: surgery characterization and electrocautery use.

A vacuum suction pump (ASF Thomas®; D-82178 Puchheim model), was used to collect the airborne PAH in the operating rooms. In the referenced pump, through a plastic extension, 5 mm syringes were connected for each surgical procedure. They contained a resin (Amberlite® XAD4) for PAH impregnation, a filter for PAH passage only in gaseous form, and polypropylene foam for fixing the XAD4 resin in the cartridge.

The referenced pump was placed at the height of the respiratory area of the workers, specifically at 7 cm from the operating field, remaining on under a flow of 120 liters per hour during each surgical procedure. The surgical time and the time of electrocautery use were timed by both a manual and a digital chronometer.

After the collection, the cartridges were disconnected from the suction pump, properly stored, and chilled for laboratory analysis for airborne components in a public university in the state of Paraná. Later, extractions of the XAD4 resin of the PAH concentrations were carried out, where the concentrations were determined by high-efficiency liquid chromatography in the referenced laboratory.

The results obtained were recorded in an Excel® 2010 spreadsheet and quantitatively analyzed by Statistical Package for the Social Sciences (SPSS) software, version 20.0. The analysis was carried out in a descriptive and analytical manner. For the descriptive analysis, central tendency and dispersion measures were applied (means, standard deviation, median, minimum, and maximum). For the analytical analysis, the Shapiro-Wilk test was applied with Spearman's Rank of Correlation Coefficient. A significance level of  $p < 0.05$  was adopted.

At all stages of this research, the ethical aspects were complied with, and approved in September, 2014 by the Human Research Ethics Committee of the institution, in accordance with regulation number 785.868.

## ● RESULTS

From the 50 samples analyzed, 17 (34%) were cholecystectomies, 27 (54%) were open surgeries, and 23 (46%) were videolaparoscopies. There were 62 health workers involved in these surgeries; 25 (40.3%) were female and 37 (59.7%) were male. Of these, 11 (17.7%) were nursing technicians, six (9.7%) nursing assistants, four (6.5%) perioperative nursing residents, six (9.7%) anesthesiologists, 11 (17.7%) anesthesiologist residents, nine (14.5%) general surgeons, and 15 (24.2%) general surgery residents.

PAHs were found in 100% of the samples, in all of the operating rooms, where the average concentration was  $0.0058 \text{ mg.m}^{-3}$ , with standard deviation of  $\pm 0.0049 \text{ mg.m}^{-3}$ .

Figure 1 shows the histogram of PAH concentration frequency and its concentrations.

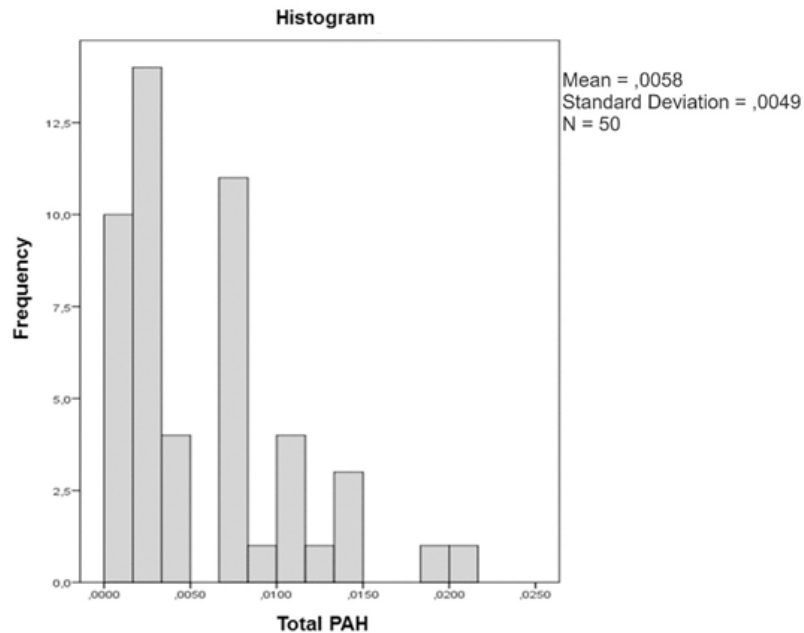


Figure 1 – Frequency of polycyclic aromatic hydrocarbon concentrations. Londrina, PR, Brazil, 2017

The average of total surgical time was 136 minutes with standard deviation of  $\pm 84$  minutes. Regarding the electrocautery use, the average was 220.5 seconds with standard deviation of  $\pm 226.4$  seconds.

Table 1 shows the descriptive statistics of the PAH concentrations, total surgical time, and time of electrocautery use.

Table 1 – Mean, minimum, maximum, median values, and standard deviation of PAH concentrations, total surgical time, and time of electrocautery use detected during surgical procedures (n=50). Londrina, PR, Brazil, 2017

Variables	Median	Mean $\pm$ standard deviation	Minimum values	Maximum values
Total PAH* [mg.m <sup>-3</sup> ]	0.0045	0.0058 $\pm$ 0.0049	0.0001	0.0208
Surgical time (minutes)	113	136 $\pm$ 84	30	443
Time of electrocautery use (seconds)	138.5	220.5 $\pm$ 226.4	13	1160

\* PAH – polycyclic aromatic hydrocarbons

Applying the Spearman test, a negative correlation was found between PAH and surgical time (-0.512) and between PAH and time of electrocautery use (-0.183).

## ● DISCUSSION

The presence of airborne PAH concentrations in the operating rooms found in this study is cause for concern, considering that the intraoperative team is constantly exposed to the chemical risk related to electrocautery smoke. Several professional categories are exposed to the referenced smoke. For example, in the United States nearly 500,000 workers are exposed per year, including surgeons, nurses, and surgical technologists.<sup>(21)</sup>

Electrocautery smoke and its effects on human health have been the focus of studies addressing not only the consequences of smoke burns in workers and the risk of explosions in operating rooms.

<sup>(22)</sup> There are also studies that attempt to measure smoke compounds and their effects on the human body.<sup>(5,7,13)</sup> However, these studies are still inconclusive, but there is strong scientific evidence of health harm to humans, including toxicity in the respiratory mucosa.<sup>(1,23)</sup>

The intraoperative team is the category that is exposed to a small amount of smoke, but for a long period of time.<sup>(1)</sup> Thus, these workers are constantly exposed to PAHs, as found in the present study.

PAH concentrations increase approximately 40 to 100 times in the air of the operating rooms after electrocautery use.<sup>(7)</sup> Therefore, previous PAH could be present in the operating rooms, but its increase as evidenced in the study confirms that the PAHs are produced by electrocautery use.

The International Agency for Research on Cancer states that the PAH benzopyrene is a human carcinogen. In addition, most hydrocarbons are likely human carcinogens, taking into account that the evidence carcinogenicity in humans is still limited and confirmed only in experimental animals.<sup>(11)</sup> One study claimed that there is risk of cancer for surgeons exposed to PAHs produced by surgical smoke, and this risk corresponded to 0.1%.<sup>(7)</sup>

Similarly to this study, PAHs were found in cross-sectional studies carried out in several countries, such as Germany, Sweden, the United Kingdom, and Switzerland, and including open and videolaparoscopic surgeries.<sup>(5,13-15)</sup>

In this study, increased PAH values were concentrated at the beginning of the surgery, as shown in Figure 1. Average values of PAH concentrations, at 0.0058 with standard deviation of 0.0049 mg.m<sup>-3</sup>, were higher than those in another other study carried out in China that identified average values of 0.0014 with standard deviation of 0.0005 mg.m<sup>-3</sup>, and a mean of 0.0010 and standard deviation of 0.0006 mg.m<sup>-3</sup>, in which the collection was taken near the surgeon and the anesthesiologist.<sup>(7)</sup>

The average surgical time in this study, 136 minutes, was similar to the other study carried out with 15 laparotomies that showed a mean of 143.3 minutes for the surgical time,<sup>(24)</sup> however, the median of 113 minutes differed from the other study that showed 614 minutes in peritonectomy surgeries.<sup>(14)</sup>

In this study, the average time of electrocautery use, 220.5 seconds, was lower than in other studies carried out in mastectomies that identified 1,986 and 1,650 seconds.<sup>(7,25)</sup> The median, 138.5 seconds, was also lower, considering that an international study identified 4,110 seconds.<sup>(8)</sup>

One study showed that there is a correlation between the amount of PAHs produced and tissue bleeding.<sup>(14)</sup> In this study, the Spearman test showed that there was a mean and negative correlation between the detected PAH concentrations and surgical time (-0.512). There is also a low and negative correlation between these concentrations and the time of electrocautery use (-0.183). Therefore, these variables are inversely proportional, because during the surgery and the electrocautery use there is a drop in PAHs present at the collection site, which was 7 cm from the operating field range.

It is assumed that, as the surgery progresses, the PAHs in the room disperse, posing a risk not only to the surgical team near the operating field, but also to other workers circulating in the room away from the operating field.

Facing this finding, the use of individual protection equipment is necessary for all intraoperative team workers. Among them there is the use of N95, N99, or N100 respirators that offer an effectiveness rate between 95% and 99.9%.<sup>(17-18,26-27)</sup>

Surgical masks, currently used in operating rooms,<sup>(28)</sup> are not appropriate, because they do not offer properly protection to workers exposed to chemical pollutants produced by smoke.<sup>(29)</sup> Allied to the use of respiratory masks, the use of safety goggles is necessary for ocular mucous membrane protection.<sup>(18)</sup>

The surgical smoke must be removed by portable ventilation systems that collect it and allow it to be filtered during both open and videolaparoscopic procedures. Among them, there is the monopolar electrosurgical pencil with coupled evacuation tubing and portable smoke evacuator.<sup>(30)</sup>

Despite the importance of the preventive measures mentioned, the author points out that there is a contemptuous attitude towards the risks of surgical smoke inhalation.<sup>(30)</sup> This practice may be related to the lack of knowledge of the worker or lack of educational policies that encourage prevention.



Therefore, it is essential that intraoperative team workers use the preventive measures mentioned for all surgical procedures, because there is a low correlation between surgical time and time of electrocautery use in relation to PAHs, which constitutes a chemical risk for the referenced workers.

As a limitation of this study, its exploratory nature is mentioned, in which it is not possible to apply it in other fields of study. Another limitation was that PAH collection was carried out only near the operating field, which was insufficient for measuring the risk for those circulating in the room who are away from the surgical area.

The results of this study collaborate for improving the public health area, occupational health, and the operating room, because it sends an alert to the scientific community regarding the risks stemming from electrocautery smoke and allows legislation and prevention programs to be implemented to avoid workers' falling ill.

## ● CONCLUSION

The results of this research confirm that there are PAHs present in the air of operating rooms stemming from the use of electrocautery smoke, in both open and videolaparoscopic surgeries, in which the highest concentrations are found at the beginning of the surgeries.

There is a mean and low inversely proportional correlation between the PAHs and surgical time and the time of electrocautery use. That is, PAHs did not increase proportionally during electrocautery use and surgical time. Therefore, there is evidence that PAHs dissipate in the air in the operating rooms.

Individual protection equipment such as respiratory masks, safety goggles, and portable evacuators are strong allies in the combat against surgical smoke inhalation, and serve as mechanisms that provide a safer occupational environment for all intraoperative team workers.

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