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## SCIENTIFIC ARTICLE

# Comparison of waste anesthetic gases in operating rooms with or without an scavenging system in a Brazilian University Hospital



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### KEYWORDS

Inhaled anesthetics;  
Operating rooms;  
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### Abstract

**Background and objectives:** Occupational exposure to waste anesthetic gases in operating room without active scavenging system has been associated with adverse health effects. Thus, this study aimed to compare the trace concentrations of the inhalational anesthetics isoflurane and sevoflurane in operating room with and without central scavenging system.

**Method:** Waste concentrations of isoflurane and sevoflurane were measured by infrared analyzer at different locations (near the respiratory area of the assistant nurse and anesthesiologist and near the anesthesia station) and at two times (30 and 120 min after the start of surgery) in both operating room types.

**Results:** All isoflurane and sevoflurane concentrations in unscavenged operating room were higher than the US recommended limit (2 parts per million), regardless of the location and time evaluated. In scavenged operating room, the average concentrations of isoflurane were within the limit of exposure, except for the measurements near the anesthesia station, regardless of the measurement times. For sevoflurane, concentrations exceeded the limit value at all measurement locations and at both times.

**Conclusions:** The exposure to both anesthetics exceeded the international limit in unscavenged operating room. In scavenged operating room, the concentrations of sevoflurane, and to a lesser extent those of isoflurane, exceeded the recommended limit value. Thus, the operating room scavenging system analyzed in the present study decreased the anesthetic concentrations, although not to the internationally recommended values.

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**PALAVRAS-CHAVE**

Anestésicos inalatórios; Salas cirúrgicas; Poluição do ar em ambientes fechados; Exposição ocupacional

**Comparação de resíduos de gases anestésicos em salas de operação com ou sem sistema de exaustão em hospital universitário brasileiro****Resumo**

*Justificativa e objetivos:* A exposição ocupacional aos resíduos de gases anestésicos em salas de operação (SO) sem sistema ativo de exaustão tem sido associada a efeitos adversos à saúde. Assim, o objetivo do estudo foi comparar os resíduos dos anestésicos inalatórios isoflurano e sevoflurano em SO com e sem sistema de exaustão.

*Método:* Concentrações residuais de isoflurano e sevoflurano foram mensuradas por analisador infravermelho em diferentes locais (próximo à área respiratória do auxiliar de enfermagem e do anesthesiologista e próximo à estação de anestesia) e em dois momentos (30 e 120 min após o início da cirurgia) em ambos os tipos de SO.

*Resultados:* Todas as concentrações de isoflurano e sevoflurano nas SO sem sistema de exaustão foram mais elevadas em relação ao valor limite recomendado pelos EUA (2 partes por milhão), independentemente do local e momento avaliados. Nas SO com sistema de exaustão, as concentrações médias de isoflurano ficaram dentro do limite de exposição, exceto para as mensurações próximas à estação de anestesia, independentemente dos momentos avaliados. Para o sevoflurano, as concentrações excederam o valor limite em todos locais de medição e nos dois momentos.

*Conclusões:* A exposição a ambos os anestésicos excedeu o limite internacional nas SO sem sistema de exaustão. Nas SO com sistema de exaustão, as concentrações de sevoflurano, e em menor extensão as de isoflurano, excederam o valor limite recomendado. Dessa forma, o sistema de exaustão das SO analisado no presente estudo diminuiu as concentrações dos anestésicos, embora não tenha reduzido a valores internacionalmente recomendados.

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**Introduction**

Occupational exposure to residual concentrations of inhaled (volatile) anesthetics in operating rooms (ORs) without scavenging system has been associated with adverse health effects, such as headache, irritability, neurobehavioral changes, and DNA damage.<sup>1</sup>

Although the cause-and-effect relationship has not yet been established, agencies in several developed countries recommend limit values for exposure to anesthetic gases to minimize health risks. The US National Institute of Occupational Safety and Health (NIOSH)<sup>2</sup> recommends the value of 2 parts per million (ppm) as occupational exposure limit to halogenated inhalational anesthetics.

Halogenated anesthetics are the most widely used agents in inhalational anesthesia worldwide. An anesthetic power measure refers to the minimum alveolar concentration (MAC). In adult patients, the halogenated sevoflurane has a MAC of about 2%, which is higher than that of isoflurane (1.2%).<sup>3</sup>

The use of inhalational anesthetics requires a scavenging system to reduce both the OR environmental contamination and occupationally exposed professionals. However, adequate OR scavenging systems are uncommon in most hospitals in developing countries. Even with the presence of an OR scavenging system in these countries, there are still large differences in efficiency between systems in developed and developing countries.<sup>4</sup>

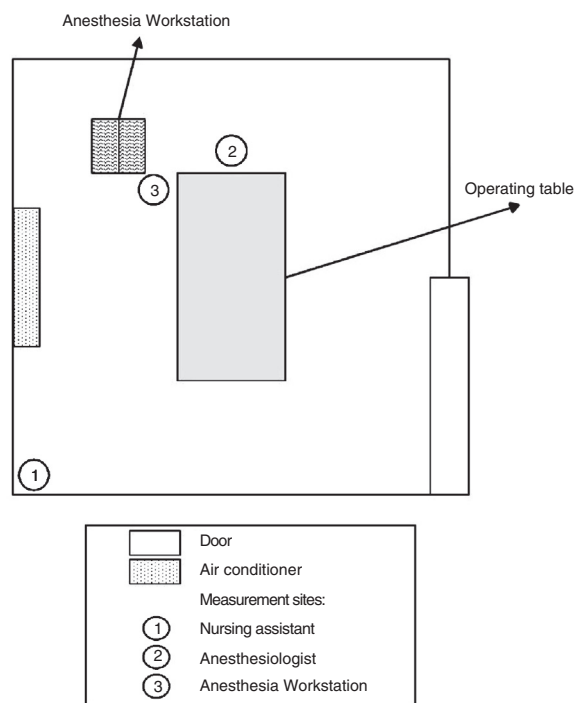
Due to the subject relevance and the absence of national data, this unpublished work aimed to compare the residual concentrations of isoflurane and sevoflurane in ORs with and without an anesthetic gas scavenging system in a public university hospital.

**Method**

This study was approved by the local Research Ethics Committee (4440-2012) and performed in a hospital with a theater setting of 13 ORs, seven of which without a scavenging system, with only one air conditioner, and six with a (partial) scavenging system with only 25% of clean external air (thus, with 75% air recirculation), with seven air changes per hour. Regarding the anesthesia stations, there was no scavenging system exclusive to inhalational anesthetics.

The study was performed in the ORs, always with the measurement of anesthetic residues during the first general anesthesia of the day, under anesthesia maintenance with isoflurane or sevoflurane, in 24 patients with tracheal intubation with cuffed tube, which was filled with minimum seal pressure to avoid leakage during artificial ventilation.

Both isoflurane and sevoflurane concentrations were used around 1 MAC, according to patient's need, with fresh gas flow (FGF) of 2 L min<sup>-1</sup> in circular breathing circuit with CO<sub>2</sub> absorber, according to the standard procedures of our hospital. The anesthesia workstation Dräger Fabius GS Premium (Germany) was used in all ORs.



**Figure 1** Diagram of operating rooms with air conditioner, without anesthetic gas scavenging system. Numbers indicate the measurement sites for residual concentration of inhaled anesthetics.

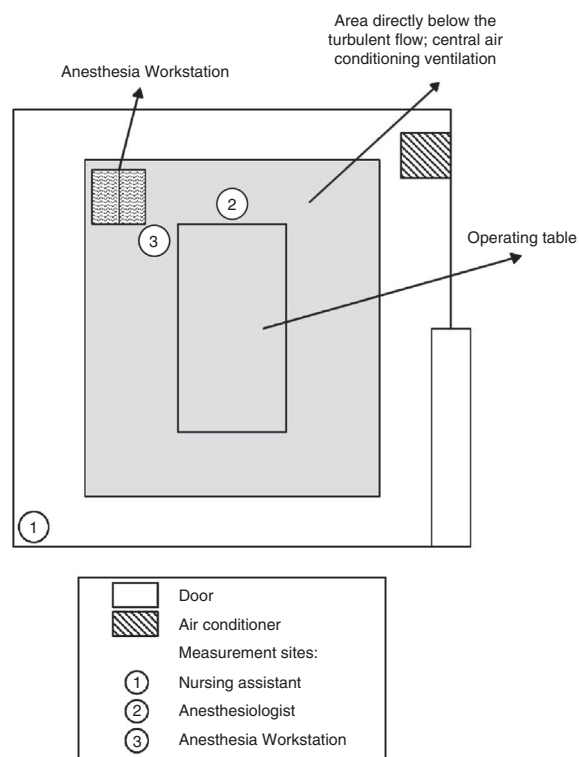
A portable anesthetic gas analyzer (InfraRan 4-Gas Anesthetic Specific Vapor Analyzer, Wilks Enterprise, USA) was used to measure the residual concentrations of both anesthetics. The analyzer detects the anesthetic concentration in real time by infrared, and the equipment detection limit ranges from 0 to 50 ppm for halogenated anesthetic agents. Air samples were measured in three sites: the anesthesiologist and nursing assistant breathing areas and near the anesthesia workstation breathing circuit (Figs. 1 and 2). Samples were collected at two times: 30 and 120 minutes (min) after the start of surgery.

Mean residual concentrations were calculated for each inhalational anesthetic at both times, at the three measurement sites and according to the OR type. Student's *t* test was used to compare times, OR types, and anesthetics. ANOVA was used to compare the measurement sites for each anesthetic, each time and type of OR. Significance levels lower than 5% were considered significant.

## Results

Table 1 shows the mean residual concentrations of isoflurane and sevoflurane measured in OR. Regarding the measurement sites, the residual concentration values in the nursing assistant and anesthesiologist breathing areas, as well as in the anesthesia workstation, were not different for both anesthetics, regardless of the OR type ( $p > 0.05$ ), with the highest values close to the anesthesia workstation.

Concentrations of both anesthetics were higher in ORs without scavenging system in all sites and times measured compared to those in ORs with scavenging system



**Figure 2** Diagram of operating rooms with central air conditioner and scavenging system (7 air changes per hour). Numbers indicate the measurement sites for residual concentration of inhaled anesthetics.

( $p < 0.001$ ). There was a significant increase in the concentrations of both isoflurane and sevoflurane at 120 min of surgery compared to 30 min only in the ORs without scavenging system at all measurement sites ( $p < 0.01$ ).

Sevoflurane concentrations were significantly higher than those of isoflurane at 120 min in the nursing assistant and anesthesiologist breathing areas in ORs with scavenging system ( $p = 0.02$ ).

## Discussion

The present study demonstrated that: (i) the use of isoflurane and sevoflurane in ORs without an anesthetic gas scavenging system resulted in mean residual concentrations that largely exceeded the 2 ppm values recommended by NIOSH; (ii) ORs with scavenging system showed mean residual isoflurane concentrations lower than that recommended by NIOSH at two of the three measurement sites; (iii) ORs with scavenging system showed mean residual sevoflurane concentrations that exceeded the NIOSH recommended limits at all sites measured.

Thus, monitoring the concentrations of halogenated anesthetic gases in OR with and without a scavenging system, as evidenced in our study, demonstrated the fundamental role of a scavenging system to remove anesthetic gas from ORs, reducing both anesthetic pollution and occupational exposure, particularly regarding isoflurane. Modern OR scavenging systems consist of a laminar flow system with at least 15 air changes per hour, without air recirculation.<sup>5</sup> With the use of appropriate scavenging systems, literature

**Table 1** Residual concentration of isoflurane (Iso) and sevoflurane (Sevo) (mean and standard deviation) in parts per million (ppm) in operating rooms with and without an anesthetic gas scavenging system. Measurements were performed at three different sites at 30 and 120 min from the start of surgery.

Types of operating room	Inhaled anesthetics (ppm)	Measurement sites					
		Nursing assistant		Anesthesiologist		Anesthesia workstation	
		30 min	120 min	30 min	120 min	30 min	120 min
Without scavenging system	Iso	5.6 (1.8)	9.5 (3.4) <sup>b</sup>	6.2 (2.0)	10.3 (3.4) <sup>b</sup>	9.7 (6.5)	13.3 (6.4) <sup>b</sup>
	Sevo	7.5 (4.7)	16.1 (8.9) <sup>b</sup>	8.5 (6.1)	16.7 (8.5) <sup>b</sup>	14.1 (11.0)	20.0 (8.1) <sup>b</sup>
With scavenging system	Iso	1.3 (0.9) <sup>a</sup>	1.1 (0.5) <sup>a</sup>	1.5 (1.1) <sup>a</sup>	1.2 (0.6) <sup>a</sup>	2.4 (1.0) <sup>a</sup>	3.6 (3.3) <sup>a</sup>
	Sevo	2.3 (1.1) <sup>a</sup>	2.9 (1.1) <sup>a,c</sup>	2.6 (1.3) <sup>a</sup>	3.3 (1.9) <sup>a,c</sup>	3.9 (2.9) <sup>a</sup>	4.8 (2.9) <sup>a</sup>

<sup>a</sup>  $p < 0.001$  compared with operating rooms without scavenging systems at all measurement sites at 30 min or 120 min.

<sup>b</sup>  $p < 0.01$  compared with 30 min in the operating rooms without scavenging system, at all sites.

<sup>c</sup>  $p = 0.02$  compared with isoflurane at 120 min in the operating rooms with scavenging system.

has shown that mean concentrations of isoflurane<sup>4,6</sup> and sevoflurane<sup>7</sup> residues were below 2 ppm. However, the anesthetic gas scavenging system present in the ORs of our surgical theater is considered partial, as it generates only seven air changes per hour, with air recirculation, with turbulent flow system. Thus, this less effective technology may explain the higher observed residual concentrations of sevoflurane, but not isoflurane. Due to its low anesthetic potency, the administration of sevoflurane should be done at MAC twice that of isoflurane, which increases the possibility of a greater residual concentration of this agent in the ORs.

Inhalational anesthetics leakage from the anesthesia workstation may also have contributed to the residual anesthetic concentrations. In fact, the highest concentrations of sevoflurane and isoflurane were found near the anesthesia workstation breathing circuit, although there were no leaks from the Dräger Fabius anesthesia workstation. It should also be considered that the more modern anesthesia workstations are likely to have less leakage, as there is a need to perform the leakage test before using the equipment.<sup>8</sup> Other causes of OR contamination include failure to shut down the flow control valves, flushing the breathing circuit with high FGF, leakage of inhaled anesthetic during filling of vaporizers, use of uncuffed tracheal tube, and use of high FGF ( $\geq 3 \text{ L min}^{-1}$ ).<sup>9</sup>

Indeed, more efforts are needed to reduce exposure to inhalational anesthetics. Frequent monitoring of anesthetic gas residual concentrations in ORs should be the first step toward understanding the values of occupational exposure in the workplace. The proper installation and operation of the OR scavenging system and use of new anesthesia workstations, as well as staff training, are also important to reduce the levels of occupational exposure.<sup>10</sup> Moreover, reducing FGF ( $\leq 1 \text{ L min}^{-1}$ ) is especially important in an environment without an active scavenging system.<sup>11</sup> In addition, the replacement of inhalational anesthetics by venous anesthetics, when possible, should be done in the absence of an adequate system to remove anesthetic gas residues in a surgical theater.<sup>4</sup>

In conclusion, our study demonstrated high residual concentrations of isoflurane and sevoflurane in ORs without

a scavenging system, which considerably exceed the values recommended by international agencies. In ORs with a partial scavenging system, the halogenated anesthetic concentrations are lower than in ORs without a scavenging system, but the exposure, particularly to sevoflurane, still exceeds the recommended limit.

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## Conflicts of interest

The authors declare no conflicts of interest.

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