IDENTIFICATION AND QUANTIFICATION OF VOLATILE ORGANIC COMPOUNDS (VOC) AND POLYCYCLIC AROMATIC HYDROCARBONS (PAH) IN OPERATING THEATERS WHERE ELECTRONIC SURGERY DEVICES WHERE USED

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INTRODUCTION

The use of electronic surgery through laparoscopic procedures has increased in the last years, becoming a very important methodology in modern surgery. Laparoscopic surgery, also called minimally invasive surgery (MIS), produces a small incision in the abdomen avoiding the larger incisions that are normally done in traditional surgical procedures. Electronic surgery dissects and burns tissue by high-frequency electric current. The destruction of tissue through heating produces smoke by-products that can contain toxic gases and vapours, bio aerosols, dead and live cellular material and viruses. The use of adequate smoke evacuation devices and precautions against inhalation have to be ensured for the operation theatre staff.

An evaluation of the concentrations of volatile organic compounds (VOC) and polycyclic aromatic hydrocarbons (PAH) was done for an operating theatre where a laparoscopic surgery was being performed. First of all, the background VOC and PAH concentrations in the empty operating theatre were evaluated. One sample was taken outdoors, where the heating, ventilating and air-conditioning (HVAC) installation gathers the outdoor air before filtering it. Two samples more were taken inside the operating room, one in the ceiling of the operating table (incoming air), and other near one ventilation exhaust located in a wall, at floor level. A second sampling was done during an operation where electronic surgery was performed. The surgical smoke produced was evacuated without being filtered. Three samples were taken, one in the outdoors HVAC air gathering, other in the environment of the operating theatre and the last located at breathing level of the doctor performing the operation.

THE AIM

To study the air quality of indoor air by the determination of organic volatile compounds in order to know the influence of smoke generated in laparoscopic techniques.

IDOOR/OUTDOOR AIR STUDY

The first step was to study the background contamination and the second was compare the differences between the background and the indoor contamination when they were carrying out a surgical operation.

MATERIALS AND METHODS

ACTIVE SAMPLING SAMPLES AND ANALYSIS

Gas phase VOC and PAH were dynamically sampled connecting custom packed glass multi-sorbent cartridge tubes (Carbotap, Carbopack X and Carboxen-569) and XAD-2 resin tubes to an air collector pump sampler SKC. Air was sampled at a velocity of 100 ml min-1.

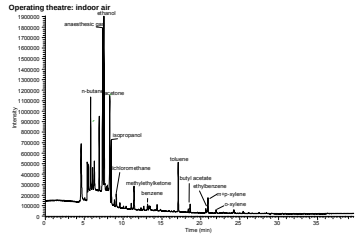
The analysis of VOCs was performed by Automatic Thermal Desorption (ATD) coupled with capillary Gas Chromatography (GC)/Mass Spectrometry (MS), using a Perkin Elmer ATD 400 (Perkin Elmer, Boston, Massachusetts, USA) and a Thermo Quest Trace 2000 GC (ThermoQuest, San Jose, California, USA) fitted with a Thermo Quest Trace Finnigan MS.(Table 1)

XAD-2 resin was desorbed with 4mL of diethyl ether in a 30 min ultrasonic bath. Previous to the extraction, a mixture of pyrene *d*-10 and benzo(ghi)perylene *d*-12 was added as a surrogate standard. The extract was reduced to near dryness under a gentle stream of nitrogen. Finally, it was redissolved in 1 ml of isooctane. The analysis of PAH was performed by GC/MS using a Thermo Quest Trace 2000 GC (Thermo Quest, San Jose, California, USA) fitted with a Thermo Quest Trace Finnigan MS, operating in electron impact and scan mode over a mass range of 30-450 u.

Table 1. -Instrumental settings and operating conditions.

TD	
Desorption temp.:	300 ºC
Desorption time:	10 min
Transfer line:	200 ºC
Cold trap sorbent Carbotrap	Tenax TA +
Cold trap low:	-30 ºC
Cold trap high:	300 ºC
Desorption flow rate:	He (50 ml/min)
Inlet split:	4 ml/min
Outlet split:	7 ml/min
Split ratio:	12 %
GC	
Capillary column:	DB-624 (60 m x 0.25 mm x 1.4 µm)
Temperature program:	40 ºC (1 min), 6ºC/min until 230 ºC (5min)
Carrier gas:	He (19.1 psi)
MS	
Interface:	250 ºC
Ionization source:	200 ºC
Ionization mode:	Electron impact
Electron energy:	70 eV
Mass range	20 - 300 amu

Figures 1. –Outdoor and indoor air Chromatograms.



FINAL REMARKS

VOCs basal concentrations obtained from the ceiling and floor levels of the studied operating theatre are found, generally, in the same order of magnitude than the concentrations obtained outdoors (Table 2). However, concentration of VOCs is favoured in indoor environments, as it can be observed by the higher concentrations of toluene and xylenes found indoors compared to outdoors, but the high level of ventilation applied in operating theatres (higher than 20 renovations per hour) assures low levels of pollution. It also has to be taken into account that several compounds daily used in operating theatres, such as ethanol, isopropanol and 1-propanol, are also found in higher concentrations than outdoors. Other compounds, such as α-pinene and limonene, are used in cleaning routines, and are also only found in the operating theatre.

PAHs were detected neither outdoors nor in the operating theatre indoor air.

VOCs concentrations obtained when an operation was being conducted (Table 3) are in the same order of magnitude than VOCs basal concentrations (Table 2), indicating that laparoscopic operations do not generate extra VOCs concentrations added to the operating theatre indoor air. Nonetheless, more research has to be done to assure this statement.

RESULTS

Table 2. Determination of COV (µg/m³) Indoor and outdoor air

Compounds	LOD	Outdoor	Operating Theatre ceiling level	Operating Theatre floor level (1)
Ethanol	3.8×10^{-4}	5.4	117.7	486.6
Acetone	2.5×10^{-4}	13.4	59.4	7.9
2-Propanol	2.5×10^{-3}	4.1	26.8	44.5
Methyl Acetate	1.6×10^{-2}	0.3	3.0	0.3
Ter-Butyl ether	2.5×10^{-4}	0.4	2.6	0.3
n-Hexane	5.1×10^{-4}	0.3	0.6	0.1
1-Propanol	1.3×10^{-2}	n.d.	1.0	5.4
Acetic acid	7.1×10^{-2}	17.2	23.1	2.4
Acetonitrile	3.8×10^{-3}	6.5	0.9	6.2
Dichloromethane	8.8×10^{-3}	1.6	4.9	0.3
Cyclopentane	1.0×10^{-2}	0.2	1.1	n.d.
3-Methyl pentane	3.8×10^{-3}	1.3	3.4	0.2
Ethyl acetate	2.5×10^{-3}	1.1	7.7	0.5
Carbon tetrachloride	5.1×10^{-3}	0.3	0.4	0.1
Benzene	1.3×10^{-4}	0.2	0.9	0.1
1-Butanol	1.0×10^{-2}	0.3	0.2	n.d.
Trichloroethylene	3.8×10^{-4}	0.1	1.5	0.1
Toluene	6.3×10^{-4}	1.3	15.5	3.0
Tetrachloroethylene	3.8×10^{-4}	0.1	1.0	0.1
n-Butyl acetate	5.1×10^{-3}	1.2	1.5	0.2
Ethyl benzene	1.3×10^{-3}	0.7.	1.6	0.2
o,m,p-Xylene	5.1×10^{-4}	1.9	4.2	0.5
α-Pinene	1.3×10^{-3}	n.d.	0.3	0.1
Decane	2.5×10^{-3}	0.2.	0.8	0.2
1,2,4- Tri-methylbenzene	3.8×10^{-3}	0.3	0.8	0.1
Limonene	6.3×10^{-3}	n.d.	0.4	n.d.
Total COV		58.1	28.3	588.8
PAH	2.2×10^{-2} 4.4×10^{-3}		n.d	

Table 3. Determination of COV (µg/m³) Indoor air during laparoscopic operation

Compounds	Outdoor (2 h)	Indoor Operating Theatre (2 h)	Personal sampling Laparoscopy (2 h)	Personal sampling Laparoscopy + scalpel (4 h)
	µg/m³ per sample			
Ethanol	n.d.	223,6	42,7	129,3
Acetone	n.d.	5,1	54,2	20,8
2- propanol	n.d.	1,4	9,8	5,8
Cyclopentene	n.d.	1,9	0,3	0,04
n-hexane	1,26	0,3	0,1	0,1
n-propanol	n.d.	0,2	1,5	0,2
Chloroform	<loq	0,6	0,2	0,1
Carbon tetrachloride	0,07	0,3	0,5	0,2
Benzene	0,03	0,3	0,4	0,2
Trichloroethylene	<loq	0,1	0,1	0,02
Toluene	<loq	0,8	1,2	0,4
tetrachloroethylene	<loq	0,1	0,1	0,04
Butyl acetate	0,03	0,1	0,3	0,1
Ethyl benzene	0,02	0,2	0,3	0,1
m+p-xylene	0,07	0,6	1,1	0,3
o-Xylene	0,05	0,2	0,4	0,1
a-Pynene	0,02	0,5	0,3	0,4
ciclohexanona	n.d.	1,0	4,0	6,1
1,2,4-trimethylbenzene	0,08	0,3	0,4	0,2
limonene	0,06	0,3	0,4	0,3

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