DOI: 10.1590/0100-69912016002009

Analysis of electrocautery generated smoke by chromatographic-mass spectrometry

Análise, mediante cromatografia/espectrometria de massas, da fumaça gerada por eletrocautério

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A B S T R A C T

Objective: to analyze the chemical components of the smoke from electrocautery from coagulating muscle and liver tissues of pigs. **Methods**: we collected smoke produced by electrocautery applied to porcine tissue in previously evacuated bottles, with qualitative and quantitative analysis of the compounds present through the hyphenated technique gas chromatography / mass spectrometry. **Results**: there was a majority of decanal aldehyde in the fumes from the subcutaneous, muscle and liver tissues. Fumes of subcutaneous and muscular tissues also showed the presence of hexanal and phenol. In the fumes of subcutaneous and liver tissues we also found toluene and limonene and, finally, nonanal smoke was present in the muscle and liver tissues. **Conclusion**: there is increasing evidence showing that smoke from electrocautery used in subcutaneous, muscle and liver tissue is harmful to human health. Thus, there is need to reduce exposure to it or wear masks with filters capable of retaining these particles.

Keywords: Smoke. Subcutaneous Tissue. Mass Spectrometry. Chromatography, Gas. Aldehydes.

INTRODUCTION

Surgical incision, dissection, coagulation and vaporization with electrocautery are widely used and recognized as a major advance in surgical technique. However, these techniques intentionally destroy tissue, creating vapors, popularly known as cautery or surgical smoke (SS)[1]. This smoke, with characteristic odor and made up of particles with micro and / or submicron size, diffuses in the environment and is inhaled by professional medical staff present in operating rooms. It is produced when the heat reaches the cells, ruptures their membranes and vaporizes its constituents, dispersing them and generating other substances during tissue combustion[2].

In vitro experiments have demonstrated the smoke constituents from the use of cautery on subcutaneous and prostate tissues, in breast lifting procedures, laparotomy and TURP[3,4]. It is known today that many of these components are toxic, mutagenic, such like the cigarette smoke, the smoke generated by a gram of tissue destroyed equals the one of six cigarettes without filter[5].

The constituents present in greater quantities in the smoke of subcutaneous tissue are hydrocarbons and nitrogen compounds, the hydrogen cyanide, formaldehyde, and benzene being the most toxic[5]. The number, proportion, the amount and nature of the substances present in the smoke depend on the tissue, on its condition and on the area under treatment with electrocautery, on the duration of the procedure, on the electric power and on the technique used (incision, coagulation, vaporization or dissection)[6].

Although there is a reasonable number of studies that analyze these constituents, the size and shape of these particles in the smoke, the interference in the surgical field visualization[7] and the use of smoke suction[8], those analyzes were performed only on the subcutaneous tissue. However, electrocautery is widely used in other tissues such as muscle and liver, producing a lot of smoke. Thus, this study aims to comparatively demonstrate which compounds are

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Table 1. *Compounds present in the ambient air sample.*

Substance	% (area)	Elution time (min)	Quality
carbon dioxide	12.35	1.464	4
ethylene oxide	12.35	1.464	3
acetonitrile	12.71	1.719	7
ethylamine	12.71	1.719	5
trimethylphosphine oxide	30.75	2.956	9
dimetilsilanodiol	30.75	2.956	9
2 chlorine 2 nitro propane	30.75	2.956	4
hexametilciclotrisiloxano	13.48	5.925	91

present in the smoke from three electrocauterized tissue, subcutaneous, muscle and liver, from pigs.

METHODS

The tissue used for the research was from a pig of the Large White breed, which is closest to human tissue[5]. The animal had its used approved for teaching and research by the Ethics Committee on Animal Use of the Biology Institute of the Universidade Estadual de Campinas.

The collection was performed at the Experimental Surgery Center of the Universidade Estadual de Campinas, with fresh tissues, using a monopolar electrocautery with 30w power, long enough to produce smoke.

The samples were collected in four vials, previously evacuated and hermetically sealed. One of the vials was used to collect air in the operating room prior to cautery use, serving as a control. In the three other vials we collected smoke from the cautery use, in pure coagulation mode, at the site of its production in the subcutaneous, muscle and liver tissues.

These previously evacuated vials are made from Pyrex glass, provided with a teflon high vacuum tap with a tap screw cap containing silicone septa for the introduction of the needle containing the gas absorbing fiber, and then introduced into the gas chromatograph using helium as the carrier gas. Before the introduction of the samples we performed the chromatogram / mass spectra of the reference (only the fiber) to verify that the peaks relating to the chromatograph eluted samples were not due to the reference. The chromatogram / mass spectra were compared with the chromatogram / mass spectra of the samples library existing in the equipment to identify the substances responsible for chromatographic peaks present in the samples collected.

The equipment used in the analysis was the gas chromatograph (Agilent 7890A model) coupled to the mass spectrometer (Agilent, 5975C model).

Table 2. *Compounds present in subcutaneous tissue sample.*

Substance	% (area)	Elution time (min)	Quality
toluene	9.93	4.395	91
hexanal	0.85	5.251	90
1.3 dimethyl benzene	0.32	7.597	93
o-xylene	0.32	7.597	93
p-xylene	0.32	7.597	93
phenol	6.82	13.445	94
limonene	0.64	15.992	90
dodecane	0.55	27.525	90
decanal	0.54	27.921	90

Table 3. *Compounds present in the muscle sample.*

Substance	% (area)	Elution time (min)	Quality
hexanal	2.97	5.238	91
tetrachloroethylene	0.77	5.501	97
heptanal	2.57	9.064	95
phenol	2.48	13.479	95
octanal	6.10	14.581	90
nonanal	13.17	21.092	91
decanal	17.84	27.900	91

The technique for sampling was Solid Phase Micro Extraction (SPME) using a needle with SUPELCO, gas-absorbing triple fiber: 50/30mm DVB/CAR/PDMS (polydimethylsiloxane), heated at 100ºC for 40 minutes to release the adsorbed compounds.

We tabulated and presented data in a qualitative way, with no statistical study.

RESULTS

The results of each sample components analysis are shown in Tables 1, 2, 3 and 4, being, respectively, the ambient air control sample, subcutaneous, muscle, and liver tissues. Tables indicate chemicals, the percentage area of the chromatographic peak for each compound, its elution time (in minutes), and quality. This last parameter refers to the degree of similarity between the detected substance and the existing compounds in the mass spectrometer database.

We found decanal in all three tissues; common substances in the smokes from subcutaneous and muscle tissues were hexanal and phenol; common compounds in the smokes from subcutaneous and liver tissues were toluene and limonene; and the common compound in the smokes from muscle and liver tissues was nonanal.

DISCUSSION

The aromatic hydrocarbon toluene has been widely found in subcutaneous tissue smoke[3]. However, there was no evidence in the literature of its presence in the smoke from liver tissue. Aldehydes have also been widely cited in the literature as present in subcutaneous tissue smoke and, as shown in this study, are not restricted to it, being also present in the smoke from muscle and liver, in the forms of hexanal, nonanal and decanal. The presence of d-limonene has not been reported in other studies in subcutaneous tissue smoke.

Wenig *et al*.[9] evaluated cautery smoke exposure in rats and noticed that they were stunned during the exposure period, returning to normal after an exposure-free period. Furthermore, when analyzing the rats' lungs, they observed vessels hypertrophy, cellular congestion and emphysematous changes. They supported the idea that these changes were from exposure to benzene, formaldehyde and acrolein, substances present in the subcutaneous tissue, muscle and liver smoke.

The presence of volatile organic compounds within the smoke, as mentioned by

Table 4. *Compounds present in the liver sample.*

Substance	% (area)	Elution time (min)	Quality
toluene	21.75	2.906	95
d-limonene	2.68	15.540	94
nonanal	3.04	20.877	86
decanal	1.43	27.822	86

Moot *et al*.[10], although in low concentrations, can chronically inflict the same health hazards of passive smoking. Furthermore, two compounds identified by this group, hydrogen cyanide and butadiene, are implicated as cardiotoxic and carcinogenic, respectively. They also showed that benzene, butadiene and decene are carcinogenic substances[10].

El Ghawabi *et al*.[11] and Chandra *et al*.[12] showed that chronic exposure to low concentrations of hydrocarbons – hexanal, heptanal, octanal, nonanal and decanal – cause headache, weakness, touch and smell changes, lacrimation, salivation, abdominal colic pain and nervous instability. Moreover, Blanc *et al*.[13] showed that hydrocarbons can lead to deficiency of vitamin B12 and folate and increase in thyroid stimulating hormone (TSH), leading to goiter. Laugesen *et al*.[14], in a review study, stated that in cigarette smoke, the butadiene amounted to 45% of the cancer risk, hydrocarbons corresponded to 89% risk of cardiovascular disease, and acrolein (aldehyde, like the others found in all three tissues) corresponded to 97% risk of lung disease.

There is growing body of evidence that the smoke produced by electrocautery used in biological tissues, be them subcutaneous, muscle or liver, is harmful to the human health. The need to reduce such exposure is evident, whether by suction of this smoke by means of suitable devices or by using surgical instruments that do not generate heat, like some kinds of laser.

ACKNOWLEDGEMENTS

We thank Dr. José Henrique Silveira Virgili for the contribution during the experimental surgery, and the staff of the Experimental Surgery Center.

R E S U M O

Objetivo: *analisar quimicamente os componentes da fumaça do eletrocautério, provenientes da coagulação de tecidos, muscular e hepático de suíno.* **Métodos:** *coleta de fumaça produzida por eletrocauterização de tecido porcino em frascos previamente evacuados com análise qualitativa e quantitativa dos compostos presentes, através de técnica hifenada, cromatografia a gás/espectrometria de massas.* **Resultados:** *houve presença majoritária do aldeído decanal nas fumaças provenientes dos tecidos subcutâneo, muscular e hepático. Fumaças dos tecidos subcutâneo e muscular mostraram também a presença de hexanal e fenol. Nas fumaças dos tecidos subcutâneo e hepático foram encontrados ainda tolueno e limoneno e, por fim, nonanal estava presente nas fumaças dos tecidos muscular e hepático.* **Conclusão:** *há número crescente de evidências mostrando que fumaça proveniente de eletrocauterização de tecidos subcutâneo, muscular e hepático é nociva à saúde de seres humanos. Portanto, há necessidade de reduzir a exposição a ela ou usar máscara com filtro capaz de reter essas partículas.*

Descritores: *Fumaça. Tecido Subcutâneo. Espectrometria de Massas. Cromatografia Gasosa. Aldeídos.*

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Received: 29/11/2015
Accepted for publication: 28/03/2016
Conflict of interest: none.
Source of funding: none.

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