

Cytotoxicity of Electro-Surgical Smoke Produced in an Anoxic Environment

Cytotoxicity of Electro-Surgical Smoke Produced in an Anoxic Environment C. Hensman FRACS A, E. L. Newman PhD A, S. M. Shimi FRCS A and A. Cuschieri MD, FRCS A ,
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Background

The effect on cell viability of smoke produced during high - frequency electro - surgery has not been previously reported. The aim of this study was to produce smoke in vitro , in a closed environment similar to that encountered in minimal access surgery , and to test its cytotoxic effects on cultured cells.

Methods

Pig liver was cut repeatedly with an electro - surgical hook knife , and the smoke generated was collected and equilibrated with cell culture medium. MCF-7 human breast carcinoma cells were exposed briefly to various dilutions of this medium and tested for clonogenicity.

Results

Electro - surgical smoke produced in a helium environment reduced the clonogenicity of the MCF-7 human breast carcinoma cells in a dose - dependent manner , falling to 30% when the cells were exposed to undiluted medium for 15 minutes.

Conclusions

We conclude that electro - surgical smoke is cytotoxic. The sublethal effects at lower dilutions are currently being investigated.

The wide acceptance of minimal access surgery (MAS) is due to its advantages in terms of patient outcome and to the development of specialized techniques adapted to surgical manipulations within a confined space with remote display of the operative field. High - frequency electro - surgery is one of the ancillary technologies used in these endoscopic interventions both for dissections and for achieving hemostasis. The hazards of smoke produced during open surgery have been documented. [1 , 2] Electro - surgical smoke is known to contain a variety of toxic chemicals including carcinogenic substances , [2] cellular material , [3] and even clumps of whole cells. [4] The use of smoke evacuation devices and safety precautions against smoke inhalation by the theater staff have been advocated during conventional open surgery. [5]

The situation is different in MAS as the smoke is produced in a closed CO₂ environment from which it is evacuated by standard suction devices. Two considerations arise from this situation. In the first instance, electro-surgical smoke produced in an anoxic environment may have a different chemical composition. Secondly, toxic chemicals generated within the closed peritoneal cavity are likely to be absorbed into the systemic circulation. Evidence for absorption of these chemicals through the peritoneal membranes during laparoscopic cavity is demonstrated by the reported increased levels of circulating carboxy and methemoglobin after these operations. [6]

We have set out to determine whether significant toxicity can arise when cultured cells are exposed for a short period of time to smoke produced in a confined space in vitro. Such a model may prove useful in the identification of the important toxic components and in the design of techniques to minimize their production.

Smoke was produced by electro-cutting 10 g portions of porcine liver inside 1 L plastic containers using a hook knife (Storz , Tuttlingen , Germany) and a high-frequency generator (Valley Lab Force FX , Colorado) . Gas (CO₂ or helium) was passed through the container via a regulator valve , to maintain a constant flow of 2.0 L per minute. The outlet was linked to the inlet port of a rotary film evaporator. This was fitted with a 500 mL round-bottomed flask containing 3 mL of the appropriate solution (see below) . Rotation was at 100 rpm , sufficient for the solution to form a thin film on the sides of the flask.

MCF-7 human breast cancer cells [7] were used for the study because of their pleural origin. They were grown in a 1 : 1 mixture of Dulbecco's modified Eagle medium and Ham's F12 nutrient mixture , supplemented with 10% fetal calf serum and antibiotics. The cells were plated into 35 mm Petri dishes at 300 cells per dish and allowed to attach overnight.

Twenty milliliters of the same medium was " smoked " as described above and then sterilized by passage through a 0.2- (μ) m filter. Medium was removed from the cells and replaced with 0.1 mL smoked medium , at doubling dilutions. After 15 minutes , this was removed and the cells washed twice with 1 mL of the normal medium. Finally , 1.0 mL of normal medium was added , and the cells were returned to the incubator. The medium was changed after 7 days , and the colonies were stained with crystal violet after 2 weeks. The experiments were conducted in triplicate.

Initial experiments using CO₂ as the carrier gas (the usual insufflating agent for MAS) were confounded by its propensity to acidify the culture medium and thereby affect clonogenicity. The results reported thus refer to experiments using helium as the carrier gas. Undiluted smoke medium was clearly cytotoxic to MCF-7 cells after only 15 minutes of exposure (Fig. 1) . The observed toxicity is dilution dependent , with reduction of clonogenicity to 30% with undiluted smoke. As the effects of the carrier gas (helium) alone were minimal , we conclude that one or more chemical components of the smoke itself were responsible for the observed cytotoxicity.

Image Caption: Fig. 1. The mean number of MCF-7 colonies observed 2 weeks after exposure to the indicated concentrations of smoked medium (dotted line , undiluted smoke = 1) . The solid line refers to clonogenic growth in untreated medium in the presence of a helium atmosphere. The experiment was carried out in triplicate.

The findings of this study have shown that electro - surgical smoke resulting from the pyrolysis of tissue in a closed anoxic environment is clearly cytotoxic to a cultured cell line. The conditions of the experiment reproduced those encountered during MAS. The data indicate the need for efficient and prompt evacuation of smoke , not just to improve the endoscopic view but also because of its toxicity. There is also the possibility for as yet undocumented sublethal effects of electro - surgical smoke (in very low dilutions) on the cellular components of the immune system and on capillary endothelium that may promote tumor implantation during MAS. These are currently being addressed in further experiments.

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