Influence of GSM Microwaves on Fractal Structure of brain tumours

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Abstract

Fractal dimension of C-6 rat glioma tumours growing in microwave field generated by signal simulation of the Global System for Mobile communications (GSM) with frequency 960 MHz was found significantly enhanced as compared with field free tumours growing at different temperatures.

1. Introduction

The Mandelbrot answer to Richardson question: "How long is the coastline of Britain ?" was concept of fractals [1]. Similar answer may be given to the question: "How long is the borderline of tumour ?", as has been found in the works of Sedivy, Landini and Rippin, Waliszewski, and several others [2-4]. In all these studies was emphasized the usefulness of fractal parameters in tumour pathology. The fractal dimension of a tumour could be understood as a measure of irregularity, which serves as an additional morphometric parameter in surgical pathology and is specific for a given tumour. Many epidemiological studies have implicated environmental and residential exposure to electromagnetic field as a possible factor in the development of certain human cancers [5-7]. Extremely low frequency electromagnetic radiation has been reported to affect a wide range of basic cellular functions, including cell proliferation [8] gene transcription and expression [9] on transport [10], protein kinase C activation [11] and cell morphology [12]. Although the detailed mechanism of the influence of a weak electromagnetic field on cellular processes is still unknown [13], electrostimulation of the proliferation of *Saccharomyces cerevisiae* [14] or *Pseudomonas stutzeri* [15], in a weak low frequency field have already direct biotechnological implications.

Recently media attention has focused on claims for damages due to alleged brain tumours, in particular glioblastomas, caused by mobile phone usage. The aim of the present communication is to study the influence of a weak AC magnetic field on rat C6 glioma cell line growing in monolayer. Glioblastomas are high-grade malignant neuroepithelial tumours having a median survival time of 8 months. These tumours have such a grim outcome in part due to their rapid volumetric growth, but also because the tumour has already grossly invaded the surrounding brain tissue long before it can be diagnosed.

As has been recently shown [16] this brain tumour model has super-rough fractal contour and therefore tumour growth may be more susceptible to external influences than ordinary three-dimensional tumours. Moreover tumour interface speed growth is in this two-dimensional case linear and not exponential [17,18] and may be characterized by one-parameter. During tumour growth and evolution, mutations continue and cells behave differently from the normal cells of the tissue where they appeared. In advanced stages of cancer, cells start to detach from the tumour and invade the blood stream or lymphatic system. They can be carried to other body parts producing new metastatic tumours. The detachment and invasion of other tissues result in part from the incorrect expression of adhesion molecules on the cell surface for the mutated genome. This process causes a decrease in cellular adhesion between cells with additional consequences such as an increase in mobility of the cells on the surface of the tumour. As a result, the boundaries of the tumour become very irregular.

This change on tumour morphology, associated with additional information, help physicians to diagnose cancer stage of development. Recent studies indicate that the fractal dimension of tumours is useful as an indicative of malignancy.

2. Material and methods

2.1. Exposure system

The microwave field was generated by signal simulation of the Global System for Mobile communications (GSM), a 960 MHz carrier amplitude modulated with a 217 Hz square pulse of duty cycle 12 %. The experimental apparatus consisted of a pair of horizontal rectangular (25cm x 15cm) coils, maintained in a pseudo-Helmholtz configuration (distance between the coils was 15cm) and powered by AC generator. Field intensities were measured using a Hall effect probe magnetometer (FW Bell, Model 9640). The cell cultures were placed in the middle part between the coils and were exposed to magnetic field and cells were allowed to grow for another 24 hours in field free box. The whole system was placed in at thermostatic box kept at 37.0 ± 0.1 °C. The temperature of the culture medium was monitored by using a nonabsorbing fluoroptic thermometry system (Luxtron 3000, Mountain View, CA, USA) and no relevant heating of medium was observed during the experiments.

2.2. Cell culture

10^4 dissociated C6 glioblastoma cells, cloned originally from rat glioma [19] and obtained from The American Type Culture Collection (Rockville, MD, USA), were plated in a 5 µl of Dulbecco's modified Eagle's medium containing 10 % (v/v) horse serum and 2.5 % (v/v) fetal-calf serum on 35 mm Petri dishes. After cells attachment 2 µl of medium was added to growing culture, which allowed tumours to grow mainly on plate surface. In a regular time intervals control and exposed tumours were photographed under the inverted microscope with a coupled digital photocamera (*Figure 1*).

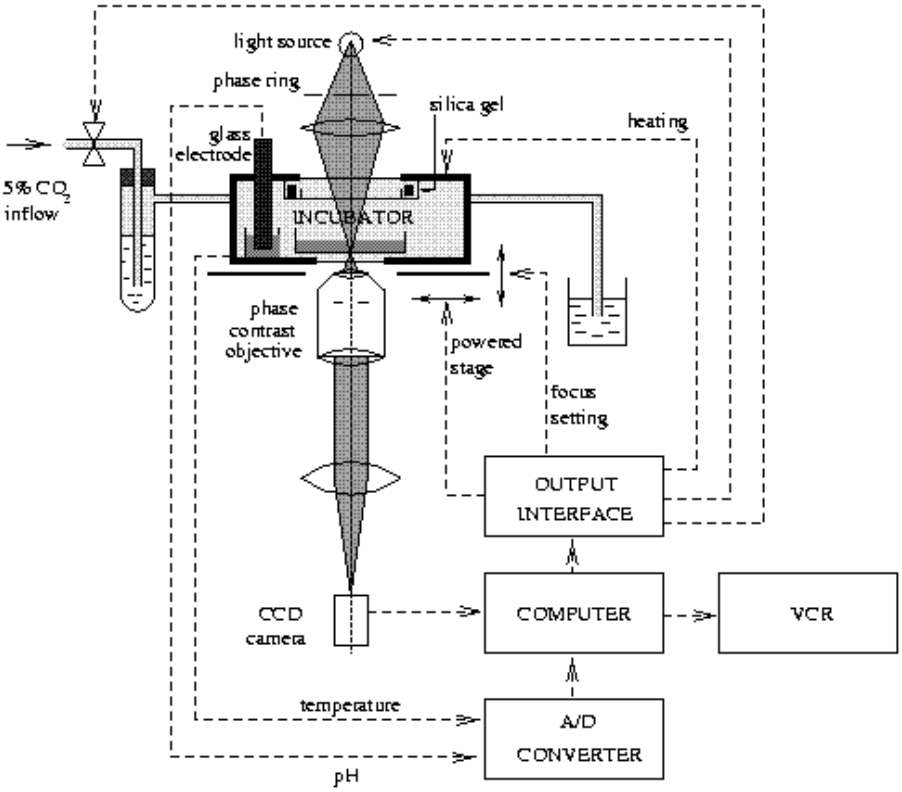

Fig. 1 Experimental setup for the study of two-dimensional tumour growth.

2.3. Determination of fractal dimension

The photographs were analyzed in a computer and tumour images were analyzed using program HarFA [20] based on the improved box counting method where binary images of tumours were covered with different grids (box length ε), and the number of boxes $N(\varepsilon)$ required to cover the structures of the nuclei was recorded. If an object is fractal, $N(\varepsilon)$ increases according to the relation

$$N(\varepsilon) = C\,\varepsilon^{D}$$

where D is fractal dimension and C is constant. From this equation the fractal dimension can be obtained as

$$D = \lim_{\varepsilon \to 0}\{-\log[N(\varepsilon)]/\log(\varepsilon)\}\,.$$

2.4. Statistical analysis

Statistical evaluation of the exponential data was performed with two-tailed Student's t-test with $p<0.05$ as the minimum level of significance.

3. Results and discussion

Fractal dimensions of tumour boundaries are shown in *Figure 2*. For the comparison we have determined fractal dimension of tumours growing at 37 °C (control), tumours growing in microwave field (GSM) and tumours growing at temperature 40 °C (heat).

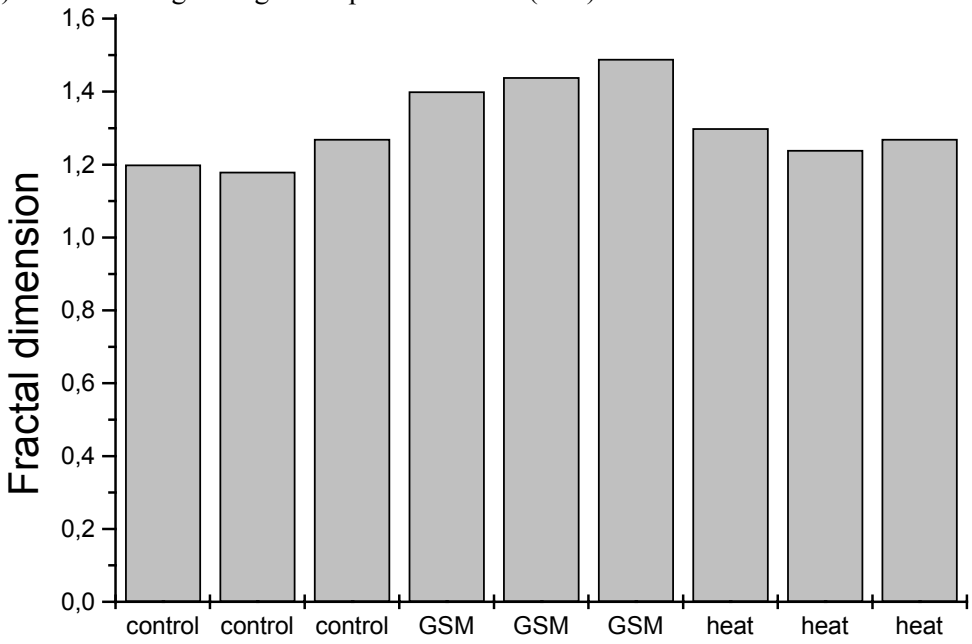

Fig. 2. Fractal dimensions of tumours boundaries at different conditions.

As is clearly seen the fractal dimension of "GSM" tumours is significantly higher than in the other two groups, which demonstrate for the first time the new effect mediated by mobile phones. It should be stressed that the intensity of used GSM microwave radiation is about 50 fold higher than the intensity which is generated by mobile phones during their common use. Nevertheless these results indicates possible role of GSM radiation not in initiation but in acceleration of brain tumour growth and metastasing activity, which is probably higher in tumours with enhanced fractal dimension.

In conclusion, our results gives evidence of altered cellular reactions responsible for tumour cells proliferation by microwaves used in mobile communication. Because the fractal dimension of tumours growing at enhanced temperature 40 ^{o}C was not significantly different from the control growth, we can only hypothesize that observed increase in tumour growth in GSM field is due to some previously suggested nonthermal mechanisms behind the cells growth during electrostimulation.

4. Acknowledgement

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5. References

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