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EFFECT OF FLUCTUATING ELECTROMAGNETIC FIELDS ON GROWTH AND CARCINOGENESIS

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Electrical fluctuations are an interesting variety of spectra of electromagnetic fields (EMF), whose effect on growth and development of living organisms had virtually not been studied. The use of such spectra in clinical and laboratory practice is limited at present to their application in physiotherapy for acute and chronic inflammatory conditions [1] and for electroanesthesia [7]. A special feature of fluctuating fields, which are usually distributed within a certain frequency range, is the presence of a "spectral distribution of energy" — a characteristic not typical of monochromatic frequencies.

The object of this investigation was to study the effect of electrical fluctuations with a gaussian spectral distribution on the kinetics of normal and malignant growth. The EMF chosen possessed minimal information content and maximal entropy.

EXPERIMENTAL METHOD

The kinetics of normal growth was studied on 120 young Wistar rats of the same age, divided into four groups. The animals of the first three groups were exposed daily to the action of a field, which began at different times — on the 28th, 45th, and 62nd days after birth, corresponding to the equivalent human age of 4.1, 7.24, and 10.37 years [2]. The duration of exposure was 15-20 days and the field intensity was 5 V/cm. The duration of each session was 1 h. The animals of group 4 were not exposed to any external influence and served as the control. Generators of types 12-1 and 12-12, by means of which the width of the spectrum* could be varied from 12 kHz to 6 MHz, served as the source of electrical fluctuations. Quantitative parameters of volume and linear growth of the rats were measured and calculated by Shmal'gauzen's method [4]. The experiments were carried out with three repetitions for each variant.

The action of fluctuating fields on malignant growth was studied on three strains of transplantable tumors: sarcoma 45, reticulosarcoma, and Walker's carcinosarcoma 256. Each series involved 140 adult rats (15-25 animals in each group). The tumors were inoculated subcutaneously into the rat's thigh as a 30% suspension. The field was applied by the con-

*The width of the spectrum of gaussian fluctuating fields usually corresponds to the frequency interval from zero to the upper limit of the spectral interval.

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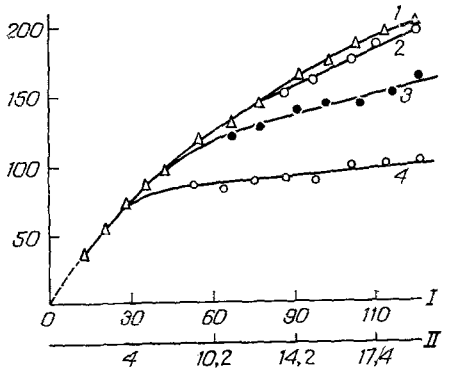

Fig. 1

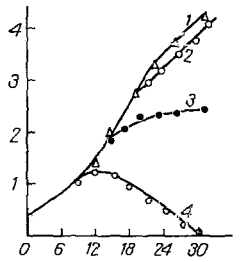

Fig. 2

Fig. 1. Changes in body weight of rats with time during exposure to fluctuating EMF. Abscissa: I) age of animals (in days); II) equivalent human age (in years); ordinate, body weight (in g). Curves 2, 3, and 4 correspond to exposure commencing on 62nd, 45th, and 28th days after birth. Curve 1 is control. Each point represents averaged value of 24 individual observations.

Fig. 2. Change in mean diameter of tumor (reticulosarcoma). Abscissa, time after exposure to EMF (in days); ordinate, diameter of tumor (in cm). Curves 2, 3, and 4 correspond to exposure to fluctuating EMF on 17th, 10th, and 2nd days after inoculation. Curve 1 is control.

tact method directly to the tumor, by the technique adopted in electrophoresis practice (current density between 0.05 and 0.1 mA/cm^2, length of session 15 min). Exposure of the tumor to the EMF began at different times after transplatation (2, 10, and 17 days) and was repeated daily for 20 days. The antitumor activity of the field was assessed by Émanuél's method [5]. A histopathological study was made of the tumor tissues and the white and red blood cells of the animals in the experimental and control group were counted and other hematological indices determined. To reduce adaptation to the field, in all experiments cold shock synchronization was carried out [3] by keeping the animals of the experimental and control group at 0°C for 30 min 8-12 h before exposure to the EMF.

EXPERIMENTAL RESULTS

The following principles of volume growth of animals exposed to the action of an EMF with normal spectral distribution were established on the basis of the experiments.

1. A low-frequency fluctuating field delayed growth of the animals. The rate of growth was 0.13, 0.17, and 0.53 in the experimental groups and 0.54 in the control. The maximal difference in weight of the experimental and control animals was 220%.

2. The younger the animal at the beginning of exposure, the stronger the inhibitory action of the EMF. With an increase in the spectral width of the fluctuations and an increase in the acting frequency up to 200 kHz, the inhibition effect weakened and was then reversed.

3. After a few sessions of irradiation the aggressiveness of the animals was steadily reduced.

4. A latent period was observed before the action of the field, the duration of which was "inversely proportional" to the animal's age.

5. Exposure of a fluctuating EMF does not induce pathological changes in the animals' blood. The scatter of the blood indices in the experiment was significantly less than in the control ($P < 0.05$). Hence it can be concluded that an EMF of the chosen parameters has a stabilizing influence on the blood system. The eosinophil count of the rats fell in the course of the experiment by 14-28% compared with normal.

Changes in the mean diameter of the tumors (reticulosarcoma) following exposure to the EMF at different times after inoculation are illustrated in Fig. 2.

It will be clear from Fig. 2 that in the earlier stages of tumor development, characterized by more rapid growth, the effectiveness of the EMF was greater. On termination of exposure (after 10-15 sessions) inhibition of growth and regression of the neoplasms continued in all experimental groups, whereas the mortality in the control group reached 91-100% for different strains. In experimental animals whose tumors regressed, no recurrences were observed over a period of six months. Pathomorphological investigation of the tumor tissue from animals of the experimental groups (tumor-bearing animals) showed, by contrast with the control, the presence of numerous coagulated conglomerates of modified tumor tissue, evidence of increased adhesion of some tumor cells under the influence of the field and, consequently, weakening of intercellular electrostatic repulsion, due to the increased negative charge density on the outer membranes of the tumor cells. The mitotic index also was lower than in the control: on average by 3-3.2 times for the reticulosarcoma and Walker's carcinoma and 2.7-3 times for sarcoma 45, evidence of a decrease in the frequency of cell division in tumors exposed to the action of low-frequency fluctuating electromagnetic fields. With an increase in the frequency ranges of the EMF above 200 kHz the antitumor effect was weakened. Within the bands of six MHG fluctuations the increase in the mean diameter of the tumors was not statistically significant and it was accompanied by their more rapid necrosis than in the control. The survival rate of these rats was 15-20% less than in the control.

Signs of regression and inhibition of growth of the tumors correlated with results obtained for other rapidly growing (embryonic) tissues, the rate of growth of which is extremely high. Delayed embryonic development and absorption of embryos took place in pregnant Wistar rats exposed to the action of fluctuating EMF in the embryonic and early fetal period. This result is opposite to that observed by Bazoky et al. [6], who found an increase in the frequency of mitosis in an embryonic tissue culture kept in a powerful electrostatic field, which was explained by these workers by a change in DNA replication during polarization of its ionic or electronic shells.

A fluctuating low-frequency electric field with gaussian spectral distribution of energy thus has a universal inhibitory action on normal and malignant growth; the maximum of this action, moreover, occurs during the period of highest growth gradients. Whereas normal growth systems are subject to the controlling systems of the body, the mechanism of division of tumor cells is largely outside the control of the system of neurohumoral regulation. It therefore seems probable that the EMF acts directly on biochemical processes linked with mitotic division of the cancer cell, possibly on nuclear metabolism.

The results indicate that, in principle, spectra of high-entropy EMF can be used as a mitotic regulator and as a method of inhibiting tumor development.

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