Letter to the Editor:

Radiofrequency Electromagnetic Fields and Possible Cancer Risk: Photochemical Aspects

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This letter is a continuation and update of previously published articles [1,2]. There have been many publications discussing potential carcinogenic effects of radiofrequency electromagnetic fields (RF-EMF) last reviewed in [3]. In order to discuss *in vivo* effects of RF-EMF, it is useful to view them in the light of photochemistry. Ordinary (thermal) reactions acquire their activation energy from random collisions between molecules. Photochemical reactions receive their activation energy through absorption of photons by molecules. The absorbed energy may produce electronically excited molecules but can also be dissipated as heat, the latter prevailing at low photon energies, insufficient for the molecular excitement. The first principle of photochemistry (Grotthuss-Draper law) is that only light that is absorbed can produce photochemical change. According to the second principle (Stark-Einstein law), a molecule absorbs a single quantum (photon) in becoming excited. If radiation is extremely intense as in a laser beam, two photons may be absorbed essentially simultaneously. Electromagnetic radiation in the visible and ultraviolet range is generally needed to produce photochemical reactions. The absorption of infrared photons from a laser can also cause reactions [4,5]. The RF-EMF photons possess even lower energies than those of the infrared rays. Generally accepted pathways by which weak RF-EMF can induce tissue or DNA damage are lacking. This pertains also to the formation of radicals as a supposed action mechanism of RF-EMF [6]. A radical pair can appear from a molecule dissociation under the impact of light (photodissociation) or heat, that is, through photochemical and thermal reactions. High temperature may cause enhanced formation of reactive oxygen species [7-10]. On the other hand, RF-EMF were reported to protect against oxidative and other cell damage [11-13]. There are no reasons to expect more chemical effects and hence biological harm per unit of absorbed energy from RF-EMF than from infrared rays believed to be harmless up to the thermal damage.

The NTP Report [14] has been discussed recently [1,15]. To sum up, exposures to GSM- or CDMA-modulated RF-EMF were associated with an increased frequency of cerebral gliomas and cardiac schwannomas in male rats [14]. However, the average life span tended to be shorter in the control animals than in exposed ones (significantly in certain SAR and gender groups); details and references are in [1,15]. The longer survival of exposed animals agrees with the concept of hormesis i.e. biphasic dose-response with a favorable effect of low doses [16-18]. The overall negative vs. positive effect expressed in the life duration seems to be more significant than the frequency of rare neoplasms associated with advanced age. Furthermore, some epidemiological studies have found an increased risk of certain tumors in populations exposed to RF-EMF. Other research did not find such associations or even reported a reduced tumor risk; references are elsewhere [1]. Epidemiological studies on health consequences of radiation exposures may be associated with bias: dose-dependent selection, self-selection and recall bias, arbitrary classification of spontaneous diseases as radiation-induced, analysis of doses ignoring background radiation and medical exposures, suppositions about incidence increase without correct comparisons with a control [18], averaging of variables over excessively wide ranges when evaluating risks, inexact construction of dose-response curves [19] etc. A moderate incidence elevation of certain cancers in some areas has been out of proportion to the tremendous development of wireless communication, being potentially attributable to the progress of neuroimaging and diagnostics in

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general. It has been assumed that the overall duration of cell phone calls roughly correlates (or did so until recently) with personal incomes [20], the latter correlating with the coverage by medical checkups, which may explain some observed associations between the cell phone use and risk of certain tumors.

Supposed harmful effects, discussed above, are from RF-EMF of subthermal intensity. At the same time, ultra high frequency (UHF) diathermy has been widely used in Russia for the treatment of sinusitis, tonsillitis and related conditions in children and adults during last 50 years at least. Associations with cancer have never been noticed [1]. Considering the anatomical adjacency of tonsils, nasal cavity, eyes and brain especially in children, there has been concern about such use of the UHF diathermy. Apparently, the estimation of the "whole-brain and lobe-specific RF-EMF doses" [21] does not always exclude thermal damage. The temperature of a whole lobe does not necessarily reflect the localized heating or hotspots. The only thinkable mechanism of tissue damage by RF-EMF on the subthermal level are hotspots due to local tissue properties (enhanced conductivity) and/or wave interference especially in motionless exposed objects. The problem of potentially damaging hotspots [22] should be studied in models and phantoms imitating e.g. the UHF-therapy of the head-and-neck area or such an "extreme" as an infant sleeping with a cell phone at his or her ear, illustrated in [23]. Magnetic resonance thermometry can be tried for this purpose [24]. Experiments with big animals such as calves or pigs, imitating UHF diathermy, could help to evaluate adverse effects, including those occurring in conditions of suboptimal focus and exposure that may come about in the routine practice. Furthermore, larger quantities of rodents should be used to achieve statistical significance. To reduce costs, it is unnecessary to examine each rodent either alive or post mortem and to search for specific neoplasms [25]. Only measurements of body temperature may be helpful. The experiments should involve the maintenance of large animal groups in equal conditions with registration of the natural life duration. The life span is known to be informative in regard to consequences of radiation exposures [26]. The doses (SAR values) and exposure duration in animals must be equivalent (taking account of the species radiosensitivity) to those in related human cohorts to make results extrapolable to humans.

In conclusion, supposed cause-effect relationships between public exposures to RF-EMF and cancer are neither satisfactorily supported by evidence nor theoretically comprehensible. Epidemiological data cannot be dismissed, but more attention should be given to potential bias.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest in this article.

ABBREVIATIONS

RF-EMF = Radiofrequency electromagnetic fields

GSM = Global System for Mobile Communication

CDMA = Code Division Multiple Access

SAR = Specific absorption rate

UHF = Ultra high frequency

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