11-7 DOSE-DEPENDENT DNA DAMAGING EFFECTS OF EXPOSURE TO RADIOFREQUENCY ELECTROMAGNETIC FIELDS (UMTS; 1950 MHZ) IN HUMAN FIBROBLASTS IN VITRO

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Objectives. UMTS (Universal Mobile Telecommunication System) is the recently introduced mobile communication standard in Europe. No information about biological effects and genotoxic properties of these particular signals is available so far. Secure use of this new technology needs knowledge about the lowest biological effective dose. Exposure to RF-Emf induces DNA strand breaks in vitro as demonstrated in diploid human fibroblasts in our labratory using different GSM signals. Therefore we tested whether RF-EMFs generated by UMTS signals have genotoxic properties as well.

Methods. We investigated if exposures to signals simulating the 3rd generation mobile system UMTS affects the frequency of DNA strand breaks and micronuclei in cultured human fibroblasts. DNA strand breaks were determined with the alkaline comet assay, the frequency of micronuclei by means of the cytokinesis-blocked micronucleus assay.
An exposure apparatus for uniform exposures of cell monolayers with bandwidths of larger than 5 MHz at 1950 MHz was developed and provided by the ITIS-foundation (Foundation for Information Technologies in Society, Zurich, Switzerland; www.itis.ethz.ch). The setup was based on two short-circuited R18 rectangular waveguides, both of which were placed inside a commercial incubator (BBD 6220, Kendro, Vienna, Austria) to ensure constant environmental conditions for cultured cells (37 °C, 5 % CO2, 95 % humidity). Two sets with six 35 mm diameter Petri dishes each were exposed simultaneously per waveguide chamber (one set exposed and the other sham-exposed). For loading the setup, the short cut could easily be removed and the cell dish holder could be placed inside positioning the Petri dishes in the H-field maxima ensured by the appropriate insets for the Petri-dish holders. Exposure was controlled by field sensors, temperature sensors for the air environment, and by an optimized air-flow system based on ventilators with a common inlet for both waveguides. The signal unit was designed for generation of the UMTS test signal. The system could be used for exposure of cell monolayers up to 17 W/kg with less than 26 % non-uniformity of the specific absorption rate (SAR). The system allowed for exposure with a temperature load of the medium less than 0.03 °C / (W/kg). The temperature difference between the waveguides did not exceed 0.1 °C. To enable blind experimentation, a computer randomly determined which of the two waveguides was exposed. Therefore, the experimenter did not know which cells had been actually exposed. This information was stored in an encoded file and uncovered by the ITIS foundation in Zurich via e-mail in exchange with the transmission of results.
Dose dependency - Continuous exposure for 24 hours was performed in all experiments with SAR values between 0.05 and 2.0 W/kg. Each experiment was conducted in quadruplicate.
Time dependency - Continuous exposure at a SAR value of 0.1 W/kg was performed in all experiments with exposure durations between 4 and 48 hours. Each experiment was

conducted in triplicate.
Intermittency - Different intermittency schemes were tested using exposure conditions proved to be optimal in the previous tests (16 hours and 0.1 W/kg). Each experiment was conducted in triplicate.

Results. Continuous exposure of cultured human fibroblasts to UMTS test signal (carrier frequency 1950 MHz) at SAR values of 1.0 and 2.0 W/kg resulted in a 2fold increase of DNA strand breaks compared to sham-treated controls at exposure durations of 16 and 24 hours ($p < 0.001$). An increased frequency of micronuclei in exposed human fibroblasts was observed after an exposure duration of 16 hours at a SAR value of 1.0 and 2.0 W/kg which was significant with the one-sided χ2-test. This increase was twofold compared to the basal level after 24 hours and reached significance using the χ2-test ($p < 0.05$) with both SAR values tested (1.0 and 2.0 W/kg).
The dose dependency of UMTS-related DNA strand breaks was investigated after continuous exposure for 24 hours. An increased comet tail factor was detected with field intensities between 0.01 and 2.0 W/kg, being significant ($p < 0.001$) at all SAR values investigated. A threefold increase compared to sham-exposed cells was detected at a SAR value of 0.1 W/kg, whereas 0.05 W/kg, 1.0 and 2.0 W/kg all yielded only a twofold increase. Again, no significant differences could be demonstrated between 1.0 and 2.0 W/kg.
Time dependency of UMTS-related genotoxic effects was evaluated using a SAR of 0.1 W/kg, because this value has proved to be most effective in the alkaline comet assay. An increased response in exposed human fibroblasts compared to sham-treated controls could be detected after 8 hours of exposure ($p < 0.05$) or longer ($p < 0.001$). Comet tail factors of exposed cells increased until a plateau was reached after an exposure duration of 20 hours. Intermittent exposure for 16 hours at a SAR of 0.1 W/kg generated slightly but significantly more DNA strand breaks in human fibroblasts compared to continuous exposure.

Conclusions. Our detailed comet assay data point to a genotoxic effect of UMTS in vitro which is confirmed by an induction of micronuclei at SAR values of 1.0 and 2.0 W/kg.

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