Does Cell Phone EMF Damage DNA?
Abstracts from 29 Studies

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Introduction

One of the most sensational and often repeated claims by alarmists is that cell phone EMF can damage DNA. If this were true, it would be a legitimate cause for concern, since DNA damage can lead to cancer. Therefore this is an area that has been the focus of much research.

The following is a collection of abstracts of in vitro and in vivo studies looking at whether cell phones can damage DNA. As this collection makes clear, the overwhelming preponderance of studies have found that cell phone radiation, even at levels that are many times higher than the exposure limit for cell phones does not cause DNA damage. The few studies that do show DNA damage are the ones that the alarmists always highlight. These studies have been analyzed by other scientists and a number of potential flaws have been identified. Most importantly, follow up studies failed to reproduce any DNA damage. In one of these false positive studies, strong evidence of scientific fraud was found. The strongest evidence is that in vivo studies on live animals (including many live-time exposures) designed to look for cancer effect did not show any adverse effects (*29).

But the alarmists deliberately ignore these facts and even insist that studies do not need to be reproducible to raise cause for concern. This is totally contrary to one of the key principles in science: All experimental results must be reproducible to be valid. Without this fundamental principle, a quack scientist could raise false alarm with any half-baked or even fraudulent experiment. This is exactly what is happening with the allegation that cell phone EMF can damage DNA. Alarmists also suggest that the preponderance of negative studies should be rejected because of “industry funding”. This is not a scientific argument, it is a conspiracy theory. Conspiracy theories are a hallmark of pseudo-science. The “industry funding” allegation is not even true for most of these studies.

This collection of studies on the effects of cell phone EMF on DNA provides an illustration of the material that expert groups use to assess the overall issue of EMF and health. The World Health Organization has published a set of guidelines for the assessment of the health risks of EMF: "*All studies, with either positive or negative effects, need to be evaluated and judged on their own merit, and then all together in a weight-of-evidence approach. It is important to determine how much a set of evidence changes the probability that exposure causes an outcome. Generally, studies must be replicated or be in agreement with similar studies. The evidence for an effect is further*

(epidemiology and laboratory) point to the same conclusion".

Expert groups from the public health organizations of more than 20 countries have issued assessments based on these guidelines. In its 2004 document entitled "What are Electromagnetic Fields: Health Effects" the World Health Organization said: "*Based on a recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields*."

Overview

There are a total of 29 studies listed. Virtually all these are so-called "in vitro" studies in which different types of biological cells were studied in test tubes. Most of the selected studies were extracted from a database maintained by the IEEE. This list is reasonably representative of studies of DNA damage, but is not an exhaustive list of all studies. Of these studies 5 were "positive" (showed DNA damage), 3 were ambiguous, and 20 were negative (no DNA damage). The positive studies that are included in this list are the ones that are most cited by alarmists.

The studies classed as ambiguous are ones in which cells were exposed to EMF and known carcinogens at the same time – DNA damage was bound to occur. The researchers tried to measure if there was any additional DNA damage when cells were also exposed to EMF. These experiments are inconclusive since the response of cells to carcinogens is highly variable and difficult to control. It is hard to tell if variation in DNA damage is due to EMF exposure, or just variable responses to the carcinogen, since both were applied at the same time.

For the "positive" studies, the most significant point is that they failed attempts at direct replication in follow up studies. The first two "positive" studies (*1, *2) listed were done by Henry Lai et al. Lai is one of the minority of scientists who are among the most vocal alarmists. See our critique of his recent article "Biological Effects of exposure to electromagnetic radiation". As has been pointed out in a the Information Statement by the COMAR committee of the IEEE: "*Follow-on research to the Lai and Singh reports at another university included an extensive study comparing different DNA damage methods and included an attempt at exact replication of the increase in DNA damage due to RF exposure (Lagroye et al. 2004* (see *11)*). Other research (Malyapa et al. 1997* (see *3, *4, *5 three separate studies)*) also failed to confirm DNA damage. The Stewart Report concluded that the evidence of Lai and Singh for DNA damage "is contradicted by a number of other studies in vivo and is not supported by in vitro work"* (IEGMP 2000, Paragraph 5.134, page 70).

A second set of "positive" studies were conducted by Hugo Rudiger et al. Rudiger's first paper was analyzed and criticized in "*Comments on: "DNA strand breaks" by Diem et al.*" (See *19). A number of potential sources of error which would invalidate the results

were identified including unreliable manual measurements, cell cycle variability, small sample size, etc. The COMAR Information Statement had this to say about Rudiger's results: "*The in vitro results published by Rudiger's lab could not be confirmed by an independent lab that attempted an exact replication (Speit et al. 2007*(see *24)*). More recently, Rudiger's results have been the subject of a scientific misconduct investigation that revealed that some of the data used in at least one publication by the group had been fabricated* (Vogel 2008). This misconduct investigation resulted from a paper by Lerchel et al. (see *28), where it was reported that the data used in the analysis appeared to have been "cooked". The University of Vienna conducted two investigations into this matter and recommended that Rudiger's paper should be withdrawn. Another independent investigation concluded that while there was no conclusive proof of fraud, the paper used: "*a not-justified scientific procedure and reduces the validity of the publication*". Finally as COMAR reported, Rudiger's results could not be replicated in a follow up experiment in another lab (*24).

In addition to the follow up studies that failed to replicate the experiments of Lai and of Rudiger, there are many other studies that have not found any DNA damage. These negative studies were much more rigorous that the ones that found damage. Many different types of cells were tested. The trials were repeated multiple times. Three studies done at the highly reputable labs of Health Canada were done at exposure levels as high as 10 W/kg (*8, *9, *10), which is 6X higher than the exposure limit for cell phones of 1.6 W/kg. A series of studies at Kyoto University found no evidence of DNA damage at up to 200 W/kg which is 125X higher (*7).

Many the studies used a series of trials in which the cells were exposed to EMF at different power levels, as well as both sham (no EMF), and "positive" exposure in which the cells were exposed to a known carcinogen (*4, *7, *8, *9, *10, *11, *13, *16, *17, *23, *27). The use of both sham and positive controls is a key characteristic of a rigorous study. In each of these studies DNA damage was detected with the carcinogen, but not with the EMF, nor the sham exposure.

Alarmists claim that "pulsed" EMF is more damaging than other forms of modulation since the peak power of a pulse is higher than the average power exposure limit. A wide range of cell phone modulation standards were tested including those using pulsed modulation. None showed any sign of damaging DNA. A couple of studies from Russia used short duration radar pulses of 300 MW/kg! These were extremely short (180 ns) but extremely powerful pulses (200 million times more than 1.6 W/kg). These studies found thermal effects (see *14 & *21), but there was no evidence of DNA damage due to non-thermal effects. The overall conclusion from these results is that none of the cell phone modulation standards including those using pulsed modulation cause DNA damage even at power levels far in excess of the exposure limit.

Reasons for Conflicting Results

The paper entitled "Controversial Cytogenetic Observations" by Vijayalaxmi and Obe (*15) provides an excellent analysis of all of the studies on DNA damage from 1990 – 2003. There were a total of 53 published studies: 31 studies (58%) found no effect, 12 (23%) that had a "positive" result (potential DNA damage), and 10 (19%) were inconclusive. The authors systematically identified sources of error, confounding factors, and/or follow up studies for each of these studies. These factors can be summarized as follows.

The studies which found no effects had the following characteristics:

- They maintained proper temperature controls and made accurate measurements of dosimetry.
- They were conducted by independent researchers in independent labs
- Replication studies were done using conditions from the original study
- The experimental protocol was described in detail
- The data were consistent
- They used large sample sizes

On the other hand, many of the "positive" studies had the following weaknesses:

- Confounding factors that might invalidate the results were discussed by the authors themselves
- The interpretation of the results was hypothetical and not supported by the experimental results
- The same researchers could not repeat their results in follow up experiments

In conclusion, the authors state that: "*The genotoxic (and epigenetic) potential of RF-radiation exposure should not be considered as "established" unless a significant increase in genotoxicity in cells exposed to RF radiation is (a) replicated by the same investigators (b) replicated and/or confirmed by independent investigators in independent laboratories and (c) such data are published in peer-reviewed journals*". These criteria have never been met by any "positive" studies. Virtually all such studies have been false positives.

The strongest evidence is that in vivo studies on live animals (including many life-time exposures) designed to look for cancer effect did not any show effects of EMF. According to the European SCENIHR (see P 57): "*animal studies are usually a more powerful experimental tool than cellular studies for assessing health risks to humans*". The following paper reviewed a total of 44 animal studies: "Radiofrequency Studies on Tumorigenesis and the Blood-Brain Barrier in Lab Animals" (*29). This review paper reached the following conclusion: "*The weight of evidence of 44 studies supports the conclusion that RF exposure within current internationally accepted limits, when given alone or in combination with carcinogens, does not affect tumorigenesis in laboratory animals and therefore, by extrapolation, RF exposure within current internationally accepted limits is unlikely to affect tumor development in human beings. Furthermore, the results showing a lack of RF effects on tum origenesis, survival and body mass in live animals offer a strong challenge to studies reporting potential genotoxic and other health effects in cells in culture and other biological samples exposed in vitro to RF energy*".

Rudiger's defense efforts

Rudiger has mounted a vigorous defense of his flawed studies and the allegations of scientific fraud. He has elicited the support of alarmist groups. Rudiger and these groups cite a few recent "positive" studies that purport to show genotoxic effects. This has not changed the assessments of expert groups associated with the world's major public health organizations. For example, the Swedish Radiation Protection Agency (SSI) commented on the Rudiger affair with the following comment in their 2010 assessment of EMF and health P 21: "*No firm conclusion can thus be drawn today, but the positive results of the Vienna group (i.e. Rudiger) are not in line with other publications*".

The European EFHRAM European Health Risk Assessment Network made the following statements in their D3 Report on Risks of EMF in vitro and in vivo 2010:
P 16 & 17: "*In the last 15 years most of the research on RF and health has been devoted to the search for non thermal biological effects of exposure. This search has been unsuccessful so far in spite of the report of many uncorrelated findings. The collection of recent papers does not change the overall picture and, on the contrary, it appears that the quality of the work in particular in terms of exposure systems and dosimetry has not been satisfactory, despite the availability of such devices and methods. Results from the high-quality studies are mostly negative*".
P 27 "*For the three frequency ranges examined, the conclusions of the 2009 SCENIHR report are still valid in spite of the publication of several positive findings. Many of the new publications originate from laboratories and countries that are new to bioelectromagnetics research. This translates sometimes into unsatisfactory dosimetry or statistical analysis. Health risk assessment to be performed in the coming years (e.g., WHO EMF project) will need to be carried out with strict quality criteria*".

Conclusion

The quantity and quality of negative both in vitro and in vivo studies over the past 30 years make it extremely unlikely that EMF within established limits causes DNA damage. It is this kind of weight of evidence that the European SCENIHR used to state in an expert report in January 2009 entitled "Health Effects of Exposure to EMF", successor to previous reports in 2005 and 2007 that came to similar conclusions (Executive Summary P 8): "*It is concluded from three independent lines of evidence (epidemiological, animal and in vitro studies) that exposure to RF fields is unlikely to lead to an increase in cancer in humans*".

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1. Acute Low-Intensity Microwave Exposure Increases DNA Single-Strand Breaks in Rat Brain Cells 1995

Bioelectromagnetics 16:207–210; 1995.

From: http://doi/10.1002/bem.2250160309/abstract

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Abstract
Levels of DNA single-strand break were assayed in brain cells from rats acutely exposed to low-intensity 2450 MHz microwaves using an alkaline microgel electrophoresis method. Immediately after 2 h of exposure to pulsed (2 ps width, 500 pulsesls) microwaves, no significant effect was observed, whereas a dose rate-dependent [0.6 and 1.2 W/kg whole body specific absorption rate (SAR)] increase in DNA single-strand breaks was found in brain cells of rats at 4 h postexposure. Furthermore, in rats exposed for 2 h to continuous-wave 2450 MHz microwaves (SAR 1.2 W/kg), increases in brain cell DNA single-strand breaks were observed immediately as well as at 4 h postexposure.

2. Single- and double-strand DNA breaks in rat brain cells after acute exposure to radiofrequency electromagnetic radiation 1996

Radiat Res 69:513–521; 1996.

From: http://www.ncbi.nlm.nih.gov/pubmed/8627134

Lai H, Singh NP

Abstract

We investigated the effects of acute (2-h) exposure to pulsed (2 - mus pulse width, 500 pulses s- 1) and continuouswave 2450-MHz radiofrequency electromagnetic radiation on DNA strand breaks in brain cells of rat. The spatial averaged power density of the radiation was 2 mW/cm^2, which produced a whole-body average-specific absorption rate of 1.2 W/kg. Single- and double-strand DNA breaks in individual brain cells were measured at 4 h post-exposure using a microgel electrophoresis assay. An increase in both types of DNA strand breaks was observed after exposure to either the pulsed or continuous-wave radiation. No significant difference was observed between the effects of the two forms of radiation. We speculate that these effects could result from a direct effect of radiofrequency electromagnetic energy on DNA molecules and/or impairment of DNA-damage repair mechanisms in brain cells. Our data further support the results of earlier in vitro and in vivo studies showing effects of radiofrequency electromagnetic radiation on DNA.

3. Measurement of DNA Damage after Exposure to 2450 MHz Electromagnetic Radiation 1997

Radiation Research: December 1997, Vol. 148, No. 6, pp. 608-617.

From:
http://www.rrjournal.org/doi/abs/10.2307/3579737?prevSearch=&searchHistoryKey=

Robert S. Malyapa, Eric W. Ahern, William L. Straube, Eduardo G. Moros, William F. Pickard, and Joseph L. Roti Roti

Recent reports suggest that exposure to 2450 MHz electromagnetic radiation causes DNA single-strand breaks (SSBs) and double-strand breaks (DSBs) in cells of rat brain irradiated in vivo (Lai and Singh, Bioelectromagnetics 16, 207-210, 1995; Int. J. Radiat. Biol. 69, 513-521, 1996). Therefore, we endeavored to determine if exposure of cultured mammalian cells in vitro to 2450 MHz radiation causes DNA damage. The alkaline comet assay (single-cell gel electrophoresis), which is reportedly the most sensitive method to assay DNA damage in individual cells, was used to measure DNA damage after in vitro 2450 MHz irradiation. Exponentially growing U87MG and C3H 10T1/2 cells were exposed to 2450 MHz continuous-wave (CW) radiation in specially designed radial transmission lines (RTLs) that provided relatively uniform microwave exposure. Specific absorption rates (SARs) were calculated to be 0.7 and 1.9 W/kg. Temperatures in the RTLs were measured in real time and were maintained at 37 ± 0.3°C. Every experiment included sham exposure(s) in an RTL. Cells were irradiated for 2 h, 2 h

followed by a 4-h incubation at 37°C in an incubator, 4 h and 24 h. After these treatments samples were subjected to the alkaline comet assay as described by Olive et al. (Exp. Cell Res. 198, 259-267, 1992). Images of comets were digitized and analyzed using a PC-based image analysis system, and the "normalized comet moment" and "comet length" were determined. No significant differences were observed between the test group and the controls after exposure to 2450 MHz CW irradiation. Thus 2450 MHz irradiation does not appear to cause DNA damage in cultured mammalian cells under these exposure conditions as measured by this assay.

4. Measurement of DNA damage after exposure to electromagnetic radiation in the cellular phone communication frequency band (835.62 and 847.74 MHz) 1997

Radiat Res 1997 Dec;148(6):618-27.

From: http://www.ncbi.nlm.nih.gov/pubmed/9399708

Malyapa RS, Ahern EW, Straube WL, Moros EG, Pickard WF, Roti Roti JL.

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Abstract

Mouse C3H 10T1/2 fibroblasts and human glioblastoma U87MG cells were exposed to cellular phone communication frequency radiations to investigate whether such exposure produces DNA damage in in vitro cultures. Two types of frequency modulations were studied: frequency-modulated continuous-wave (FMCW), with a carrier frequency of 835.62 MHz, and code-division multiple-access (CDMA) centered on 847.74 MHz. Exponentially growing (U87MG and C3H 10T1/2 cells) and plateau-phase (C3H 10T1/2 cells) cultures were exposed to either FMCW or CDMA radiation for varying periods up to 24 h in specially designed radial transmission lines (RTLs) that provided relatively uniform exposure with a specific absorption rate (SAR) of 0.6 W/kg. Temperatures in the RTLs were monitored continuously and maintained at 37 +/- 0.3 degrees C. Sham exposure of cultures in an RTL (negative control) and 137Cs gamma-irradiated samples (positive control) were included with every experiment. The alkaline comet assay as described by Olive et al. (Exp. Cell Res. 198, 259-269, 1992) was used to measure DNA damage. No significant differences were observed between the test group exposed to FMCW or CDMA radiation and the sham-treated negative controls. Our results indicate that exposure of cultured mammalian cells to cellular phone communication frequencies

under these conditions at an SAR of 0.6 W/kg does not cause DNA damage as measured by the alkaline comet assay.

5. DNA Damage in Rat Brain Cells after In Vivo Exposure to 2450 MHz Electromagnetic Radiation and Various Methods of Euthanasia 1998

Radiation Research: June 1998, Vol. 149, No. 6, pp. 637-645.

From:
http://www.rrjournal.org/doi/abs/10.2307/3579911?prevSearch=&searchHistoryKey=

Robert S. Malyapa, Eric W. Ahern, Chen Bi, William L. Straube, Marie LaRegina, William F. Pickard, and Joseph L. Roti Roti

The present study was done to confirm the reported observation that low-intensity acute exposure to 2450 MHz radiation causes DNA single-strand breaks (Lai and Singh, Bioelectromagnetics 16, 207-210, 1995). Male Sprague-Dawley rats weighing approximately 250 g were irradiated with 2450 MHz continuous-wave (CW) microwaves for 2 h at a specific absorption rate of 1.2 W/kg in a cylindrical waveguide system (Guy et al., Radio Sci. 14, 63-74, 1979). There was no associated rise in the core body temperature of the rats. After the irradiation or sham treatments, rats were euthanized by either CO_2 asphyxia or decapitation by guillotine (eight pairs of animals per euthanasia group). After euthanasia the brains were removed and immediately immersed in cold Ames medium and the cells of the cerebral cortex and the hippocampus were dissociated separately and subjected to the alkaline comet assay. Irrespective of whether the rats were euthanized by CO_2 asphyxia or decapitated by guillotine, no significant differences were observed between either the comet length or the normalized comet moment of cells from either the cerebral cortex or the hippocampus of sham-treated rats and those from the irradiated rats. However, the data for the rats asphyxiated with CO_2 showed more intrinsic DNA damage and more experiment-to-experiment variation than did the data for rats euthanized by guillotine. Therefore, the guillotine method of euthanasia is the most appropriate in studies relating to DNA damage. Furthermore, we did not confirm the observation that DNA damage is produced in cells of the rat cerebral cortex or the hippocampus after a 2-h exposure to 2450 MHz CW microwaves or at 4 h after the exposure.

6. Measurement of DNA Damage in Mammalian Cells Exposed In Vitro to RF Fields of 3-5W/kg 2001

Radiation Research 156, 328-332 (2001)

From: http://www.ncbi.nlm.nih.gov/pubmed/11500143

Li Li, Kheem S. Bisht, Isabelle LaGroye, Peng Zhang, William L Straube, et al

Abstract

In the present study, we determined whether exposure of mammalian cells to 3.2 – 5.1 W/kg specific absorption rate (SAR) radiofrequency fields could induce DNA damage in murine C3H 10T1/2 fibroplasts. Cell cultures were exposed to 847,74 MHZ code-division multiple access (CDMA) and 835.62 frequency-division multiple access (FDMA) modulated radiations in radial transmission line (RTL) irradiators in which the temperature was regulated to 37.0 +/- 0.3 C. Using the alkaline comet assay to measure DNA damage, we found no statistically significant differences in either comet moment or comet length between sham-exposed cells and those exposed for 2, 4 or 24 h to CDMA or FDMA radiations in either exponentially growing or plateau phase cells. Further, a 4-h incubation after the 2-h exposure resulted in no significant changes in comet moment or comet length. Our results sow that exposure of cultured C3H 10T1/2 cells at 37 C CDMA or FDMA at SAR values of up to 5.1W/kg did not induce measurable DNA damage.

7. Effects of High-Frequency Electromagnetic Fields on DNA Breaks Using Comet Assay Method 2002

Junji Miyakoshi, Masami Yoshida, Yosiaaki Tarusawa, et al. Kyoto University Electrical Engineering in Japan, Val. 141, No. 4, 2002

From: http://ieee-emf.com/viewstudy.cfm?ID=326

In Vitro 1.5 GHz (PDC), 2.1 GHz (UMTS, CW), 2.4 GHz (CW) exposure to MO54 and CHO-K1 cells and analysis of DNA damage

MO54 and CHO-K1 cells were exposed to 2450 MHz (CW, PW) RF at high SARs (5 to 200 W/kg). In an initial study, exposure for 2 days at up to 50 W/kg in a circular waveguide +/- co-treatment with bleomycin had no effect on HGPRT locus mutations, and exposure at up to 100 W/kg had no effect on DNA strand breaks using an alkaline comet assay. In the 2005 study, human malignant glioma MO54 cells were exposed to 2450 MHz for 2 hrs at SARs of 5, 10, 20, 50, 100 and 200W/kg. Thermal controls were performed at 39, 41 and 44 ºC. The authors report no significant effects on DNA damage

as measured by tail moment, tail length and tail percent in comet assays at SARs up to 200 W/kg, although effects were observed using bleomycin (positive control) treatment. In a 2006 publication, the authors reported a similar lack of effects in human glioblastoma A172 cells and normal human IMR-90 fibroblasts exposed to 2.1 GHz (UMTS, CW) RF at up to 0.8 W/kg for 2 or 24 h (~simulating base station exposure levels as defined by the ICNIRP whole body limits).

Effects (only at thermal levels) Completed With Publication
Hirosaki University, Japan - miyskosh@cc.hirosaki-u.ac.jp

8. DNA damage and micronucleus induction in human leukocytes after acute in vitro exposure to a 1.9 GHz continuous-wave radiofrequency field 2002

Radiat Res. 2002 Oct;158(4):523-33.

From: http://www.ncbi.nlm.nih.gov/pubmed/12236820

McNamee JP, Bellier PV, Gajda GB, Miller SM, Lemay EP, Lavallée BF, Marro L, Thansandote A.

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Abstract

Human blood cultures were exposed to a 1.9 GHz continuous-wave (CW) radiofrequency (RF) field for 2 h using a series of six circularly polarized, cylindrical waveguides. Mean specific absorption rates (SARs) of 0.0, 0.1, 0.26, 0.92, 2.4 and 10 W/kg were achieved, and the temperature within the cultures during a 2-h exposure was maintained at 37.0 +/- 0.5 degrees C. Concurrent negative (incubator) and positive (1.5 Gy (137)Cs gamma radiation) control cultures were run for each experiment. DNA damage was quantified immediately after RF-field exposure using the alkaline comet assay, and four parameters (tail ratio, tail moment, comet length and tail length) were used to assess DNA damage for each comet. No evidence of increased primary DNA damage was detected by any parameter for RF-field-exposed cultures at any SAR tested. The formation of micronuclei in the RF-field-exposed blood cell cultures was assessed using the cytokinesis-block micronucleus assay. There was no significant difference in the binucleated cell frequency, incidence of micronucleated binucleated cells, or total incidence of micronuclei between any of the RF-field-exposed cultures and the sham-exposed controls at any SAR tested. These results do not support the hypothesis that acute, nonthermalizing 1.9 GHz CW RF-field exposure causes DNA damage in cultured human leukocytes.

9. DNA damage in human leukocytes after acute in vitro exposure to a 1.9 GHz pulse-modulated radiofrequency field 2002

Radiat Res 2002 Oct;158(4):534-7

From: http://www.ncbi.nlm.nih.gov/pubmed/12236821

McNamee JP, Bellier PV, Gajda GB, Lavallée BF, Lemay EP, Marro L, Thansandote A.

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Abstract

Blood cultures from human volunteers were exposed to an acute 1.9 GHz pulse-modulated radiofrequency (RF) field for 2 h using a series of six circularly polarized, cylindrical waveguides. Mean specific absorption rates (SARs) ranged from 0 to 10 W/kg, and the temperature within the cultures during the exposure was maintained at 37.0 +/- 0.5 degrees C. DNA damage was quantified in leukocytes by the alkaline comet assay and the cytokinesis-block micronucleus assay. When compared to the sham-treated controls, no evidence of increased primary DNA damage was detected by any parameter for any of the RF-field-exposed cultures when evaluated using the alkaline comet assay. Furthermore, no significant differences in the frequency of binucleated cells, incidence of micronucleated binucleated cells, or total incidence of micronuclei were detected between any of the RF-field-exposed cultures and the sham-treated control at any SAR tested. These results do not support the hypothesis that acute, nonthermalizing 1.9 GHz pulse-modulated RF-field exposure causes DNA damage in cultured human leukocytes.

10. No Evidence for Genotoxic Effects from 24 h Exposure of Human Leukocytes to 1.9 GHz RF Fields 2003

RADIATION RESEARCH **159**, 693–697 (2003)

From: http://www.rrjournal.org/doi/abs/10.1667/0033-7587%282003%29159%5B0693%3ANEFGEF%5D2.0.CO%3B2

McNamee JP, Bellier PV, Gajda GB, Lavallée BF, Lemay EP, Marro L, Thansandote A.

Abstract

The current study extends our previous investigations of 2-h radiofrequency (RF)-field exposures on genotoxicity in human blood cell cultures by examining the effect of 24-h continuous-wave (CW) and pulsed-wave (PW) 1.9 GHz RF-field exposures on both primary DNA damage and micronucleus induction in human leukocyte cultures. Mean specific absorption rates (SARs) ranged from 0 to 10 W/kg, and the temperature within the cultures was maintained at 37.0 6 1.08C for the duration of the 24-h exposure period. No significant differences in primary DNA damage were observed between the sham-treated controls and any of the CW or PW 1.9 GHz RF field- exposed cultures when processed immediately after the exposure period by the alkaline comet assay. Similarly, no significant differences were observed in the incidence of micronuclei, incidence of micronucleated binucleated cells, frequency of binucleated cells, or proliferation index between the sham-treated controls and any of the CW or PW 1.9 GHz RF field- exposed cultures. In conclusion, the current study found no evidence of 1.9 GHz RF-field-induced genotoxicity in human blood cell cultures after a 24-h exposure period.

11. Measurement of DNA damage after acute exposure to pulsed-wave 2450MHz microwaves in rat brain cells by two alkaline comet assay methods 2004

This is another refutation of the Lai & Singh experiments that was cited in the COMAR report.

INT. J. RADIAT. BIOL. , JANUARY, 2004, VOL. 80, NO. 1, 11–20

From:
http://informahealthcare.com/doi/abs/10.1080/09553000310001642911?prevSearch=authorsfield%253A%2528Laregina%252C%2BM.%2529&searchHistoryKey=

I. LAGROYE, R. ANANE, B. A. WETTRING, E. G. MOROS, W. L. STRAUBE, M. LAREGINA, M. NIEHOFF, W. F. PICKARD, J. BATY and J. L. ROTI

Abstract

Purpose: To investigate the effect of 2450MHz pulsed-wave microwaves on the induction of DNA damage in brain cells of exposed rats and to discover whether proteinase K is needed to detect DNA damage in the brain cells of rats exposed to 2450MHz microwaves.

Materials and methods: Sprague–Dawley rats were exposed to 2450MHz pulsed-wave microwaves and sacrificed 4 h after a 2-h exposure. Rats irradiated whole-body with 1Gy 137Cs were included as positive controls. DNA damage was assayed by two variants of the alkaline comet assay on separate aliquots of the same cell preparation.

Results: Significant DNA damage was observed in the rat brain cells of rats exposed to c-rays using both versions of the alkaline comet assay independent of the presence or absence of proteinase K. However, neither version of the assay could detect any difference in comet length and/or normalized comet moment between sham- and 2450MHz pulsed-wave microwave-exposed rats, regardless of the inclusion or omission of proteinase K in the comet assay.

Conclusions: No DNA damage in brain cells was detected following exposure of rats to 2450MHz microwaves pulsed-wave at a specific absorption rate of 1.2W/kg regardless of whether or not proteinase K was included in the assay. Thus, the results support the conclusion that low-level 2450MHz pulsed-wave microwave exposures do not induce DNA damage detectable by the alkaline comet assay.

12. Measurement of DNA Damage and Apoptosis in Molt-4 Cells after In Vitro Exposure to RF Radiation 2004

Radiation Res 161, 193-200 (2004)

From: http://www.rrjournal.org/doi/abs/10.1667/RR3127

Graham J. Hook, Peng Zhang, I. Lagroye, Li Li, Ryuji Higashikubo, Edurard G Moros, William L Staube, Willaim F Pickard, Jack D Baty, and Joseph L Roti

To determine whether exposure to radiofrequency (RF) radiation can induce DNA damage or apoptosis, Molt-4 T lymphoblastoid cells were exposed with RF fields at frequencies and modulations of the type used by wireless communication devices. Four types of frequency/modulation forms were studied: 847.74 MHz code-division multiple-access (CDMA), 835.62 MHz frequency-division multiple-access (FDMA), 813.56 MHz iDEN® (iDEN), and 836.55 MHz time-division multiple-access (TDMA). Exponentially growing cells were exposed to RF radiation for periods up to 24 h using a radial transmission line (RTL) exposure system. The specific absorption rates used were 3.2 W/kg for CDMA and FDMA, 2.4 or 24 mW/kg for iDEN, and 2.6 or 26 mW/kg for TDMA. The temperature in the RTLs was maintained at 37°C ± 0.3°C. DNA damage was measured using the single-cell gel electrophoresis assay. The annexin V affinity assay was used to detect apoptosis. No statistically significant difference in the level of

DNA damage or apoptosis was observed between sham-treated cells and cells exposed to RF radiation for any frequency, modulation or exposure time. Our results show that exposure of Molt-4 cells to CDMA, FDMA, iDEN or TDMA modulated RF radiation

13. Measurements of Alkali-Labile DNA Damage and Protein–DNA Crosslinks after 2450 MHz Microwave and Low-Dose Gamma Irradiation In Vitro 2004

Radiation Research: February 2004, Vol. 161, No. 2, pp. 201-214

From: http://www.rrjournal.org/doi/abs/10.1667/RR3122

Lagroyea, G. J. Hook, B. A. Wettring, J. D. Baty, E. G. Moros, W. L. Straube, and J. L. Roti Roti

Abstract

In vitro experiments were performed to determine whether 2450 MHz microwave radiation induces alkali-labile DNA damage and/or DNA–protein or DNA–DNA crosslinks in C3H 10T½ cells. After a 2-h exposure to either 2450 MHz continuous-wave (CW) microwaves at an SAR of 1.9 W/kg or 1 mM cisplatinum (CDDP, a positive control for DNA crosslinks), C3H 10T½ cells were irradiated with 4 Gy of γ rays (^{137}Cs). Immediately after γ irradiation, the single-cell gel electrophoresis assay was performed to detect DNA damage. For each exposure condition, one set of samples was treated with proteinase K (1 mg/ml) to remove any possible DNA–protein crosslinks. To measure DNA–protein crosslinks independent of DNA–DNA crosslinks, we quantified the proteins that were recovered with DNA after microwave exposure, using CDDP and γ irradiation, positive controls for DNA–protein crosslinks. Ionizing radiation (4 Gy) induced significant DNA damage. However, no DNA damage could be detected after exposure to 2450 MHz CW microwaves alone. The crosslinking agent CDDP significantly reduced both the comet length and the normalized comet moment in C3H 10T½ cells irradiated with 4 Gy γ rays. In contrast, 2450 MHz microwaves did not impede the DNA migration induced by γ rays. When control cells were treated with proteinase K, both parameters increased in the absence of any DNA damage. However, no additional effect of proteinase K was seen in samples exposed to 2450 MHz microwaves or in samples treated with the combination of microwaves and radiation. On the other hand, proteinase K treatment was ineffective in restoring any migration of the DNA in cells pretreated with CDDP and irradiated with γ rays. When DNA–protein crosslinks were specifically measured, we found no evidence for the induction of DNA–protein crosslinks or changes in amount of the protein associated with DNA by 2450 MHz CW microwave exposure. Thus 2-h exposures to 1.9 W/ kg of 2450 MHz CW microwaves did not induce measurable alkali-labile DNA damage or DNA–DNA or DNA–protein crosslinks.

14. DNA damage in frog erythrocytes after in vitro exposure to a high peak-power pulsed electromagnetic field. 2004

Mutat Res. 2004 Mar 14;558(1-2):27-34.

From: http://www.ncbi.nlm.nih.gov/pubmed/15036116

Chemeris NK, Gapeyev AB, Scrota NP, Gudkova OY, Kornienko NV, Tankanag AV, Konovalov IV, Buzoverya ME, Suvorov VG, Logunov VA.

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Abstract

Till the present time, the genotoxic effects of high peak-power pulsed electromagnetic fields (HPPP EMF) on cultured cells have not been studied. We investigated possible genotoxic effects of HPPP EMF (8.8 GHz, 180 ns pulse width, peak power 65 kW, repetition rate 50 Hz) on erythrocytes of the frog Xenopus laevis. We used the alkaline comet assay, which is a highly sensitive method to assess DNA single-strand breaks and alkali-labile lesions. Blood samples were exposed to HPPP EMF for 40 min in rectangular wave guide. The specific absorption rate (SAR) calculated from temperature kinetics was about 1.6 kW/kg (peak SAR was about 300 MW/kg). The temperature rise in the blood samples at steady state was 3.5 +/- 0.1 degrees C. The data show that the increase in DNA damage after exposure of erythrocytes to HPPP EMF was induced by the rise in temperature in the exposed cell suspension. This was confirmed in experiments in which cells were incubated for 40 min under the corresponding temperature conditions. The results allow us to conclude that HPPP EMF-exposure at the given modality did not cause any a-thermal genotoxic effect on frog erythrocytes in vitro.

15. Controversial Cytogenetic Observations in Mammalian Somatic Cells Exposed to Radiofrequency Radiation 2004

Radiation Research: November 2004, Vol. 162, No. 5, pp. 481-496.

From: http://www.rrjournal.org/doi/abs/10.1667/RR3252

Vijayalaxmi and Obe, G

Abstract

During the years 1990–2003 a large number of investigations were conducted using rodents, cultured rodent and human cells, and freshly collected human blood lymphocytes to determine the genotoxic potential of exposure to radiofrequency (RF) radiation. The results of most of these studies (58%) did not indicate increased damage to the genetic material (assessed from DNA strand breaks, incidence of chromosomal aberrations, micronuclei and sister chromatid exchanges) in cells exposed to RF radiation compared to sham-exposed and/or unexposed cells. Some investigations (23%) reported an increase in such damage in cells exposed to RF radiation. The observations from other studies (19%) were inconclusive. This paper reviews the investigations published in scientific journals during 1990–2003 and attempts to identify probable reason(s) for the conflicting results. Recommendations are made for future research to address some of the controversial observations.

16. Genotoxicity evaluation of electromagnetic fields generated by 835-MHz mobile phone frequency band. 2005

Eur J Cancer Prev. 2005 Apr;14(2):175-9.

From: http://www.ncbi.nlm.nih.gov/pubmed/15785322

Chang SK, Choi JS, Gil HW, Yang JO, Lee EY, Jeon YS, Lee ZW, Lee M, Hong MY, Ho Son T, Hong SY.

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Abstract

It is still unclear whether the exposure to electromagnetic fields (EMFs) generated by mobile phone radiation is directly linked to cancer. We examined the biological effects of an EMF at 835 MHz, the most widely used communication frequency band in Korean CDMA mobile phone networks, on bacterial reverse mutation (Ames assay) and DNA stability (in vitro DNA degradation). In the Ames assay, tester strains alone or combined with positive mutagen were applied in an artificial mobile phone frequency EMF generator with continuous waveform at a specific absorption rate (SAR) of 4 W/kg for 48 h. In the presence of the 835-MHz EMF radiation, incubation with positive mutagen 4-nitroquinoline-1-oxide and cumene hydroxide further increased the mutation rate in Escherichia coli WP2 and TA102, respectively, while the contrary results in Salmonella

typhimurium TA98 and TA1535 treated with 4-nitroquinoline-1-oxide and sodium azide, respectively, were shown as antimutagenic. However, these mutagenic or co-mutagenic effects of 835-MHz radiation were not significantly repeated in other relevant strains with same mutation type. In the DNA degradation test, the exposure to 835-MHz EMF did not change the rate of degradation observed using plasmid pBluescript SK(+) as an indicator. Thus, we suggest that 835-MHz EMF under the conditions of our study neither affected the reverse mutation frequency nor accelerated DNA degradation in vitro.

17. Studying the synergistic damage effects induced by 1.8 GHz radiofrequency field radiation (RFR) with four chemical mutagens on human lymphocyte DNA using comet assay in vitro 2005

Mutation Research 578 (2005) 149–157

From: http://www.ncbi.nlm.nih.gov/pubmed/15935405

Wang Baohong, He Jiliang, Jin Lifen, Lu Deqiang, Zheng Wei, Lou Jianlin, Deng Hongping

Abstract

The aim of this investigation was to study the synergistic DNA damage effects in human lymphocytes induced by 1.8 GHz radiofrequency field radiation (RFR, SAR of 3 W/kg) with four chemical mutagens, i.e. mitomycin C (MMC, DNA crosslinker), bleomycin (BLM, radiomimetic agent), methyl methanesulfonate(MMS,alkylating agent), and 4 nitroquinoline-1-oxide (4NQO, UV-mimetic agent). The DNA damage of lymphocytes exposed to RFR and/or with chemical mutagens was detected at two incubation time (0 or 21 h) after treatment with comet assay in vitro. Three combinative exposure ways were used. Cells were exposed to RFR and chemical mutagens for 2 and 3 h, respectively. Tail length (TL) and tail moment (TM) were utilized as DNA damage indexes. The results showed no difference of DNA damage indexes between RFR group and control group at 0 and 21 h incubation after exposure ($P > 0.05$). There were significant difference of DNA damage indexes between MMC group and RFR +MMC co-exposure group at 0 and 21 h incubation after treatment ($P < 0.01$). Also the significant difference of DNA damage indexes between 4NQO group and RFR + 4NQO co-exposure group at 0 and 21h incubation after treatment was observed ($P < 0.05$ or $P < 0.01$). The DNA damage in RFR +BLM co-exposure groups and RFR +MMS co-exposure groups was not significantly increased, as compared with corresponding BLM and MMS groups ($P > 0.05$). The experimental results indicated 1.8 GHz RFR (SAR, 3 W/kg) for 2 h did not induce the human lymphocyte DNA damage effects in vitro, but could enhance the

human lymphocyte DNA damage effects induced by MMC and 4NQO. The synergistic DNA damage effects of 1.8 GHz RFR with BLM or MMS were not obvious.

18. Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. 2005

Mutat Res. 2005 Jun 6;583(2):178-83.

From: http://www.ncbi.nlm.nih.gov/pubmed/15869902

Diem E, Schwarz C, Adlkofer F, Jahn O, Rüdiger H.

Division of Occupational Medicine, Medical University of Vienna, Waehringer Guertel 18-20, Vienna 1090, Austria.

Comment in:

- Mutat Res. 2009 Feb 19;673(1):2.
- Mutat Res. 2006 Jan 31;603(1):104-6; author reply 107-9.
- Mutat Res. 2009 Feb 19;673(1):1.
- Mutat Res. 2010 Jan;695(1-2):1.
- Mutat Res. 2010 Mar 29;697(1-2):60-5.

Abstract

Cultured human diploid fibroblasts and cultured rat granulosa cells were exposed to intermittent and continuous radiofrequency electromagnetic fields (RF-EMF) used in mobile phones, with different specific absorption rates (SAR) and different mobile-phone modulations. DNA strand breaks were determined by means of the alkaline and neutral comet assay. RF-EMF exposure (1800 MHz; SAR 1.2 or 2 W/kg; different modulations; during 4, 16 and 24h; intermittent 5 min on/10 min off or continuous wave) induced DNA single- and double-strand breaks. Effects occurred after 16 h exposure in both cell types and after different mobile-phone modulations. The intermittent exposure showed a stronger effect in the comet assay than continuous exposure. Therefore we conclude that the induced DNA damage cannot be based on thermal effects.

19. Comments on: “DNA strand breaks” by Diem et al. [Mutant. Res. 583 (2005) 178–183] and Ivancsits et al. [Mutat. Res. 583 (2005) 184–188] 2006

Mutation Research 603 (2006) 104–106

From: http://www.ncbi.nlm.nih.gov/pubmed/16384726

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In conclusion, a ‘potential’ increase in the number of confounding cells (S-phase with replication forks induced strand breaks and/or ‘apoptotic cells’ with severely fragmented DNA) in RFR- and ELF–EMF exposed cells, relative to sham-exposed samples, would certainly increase the number of cells classified into category E. For every 1% increase in confounding cells in category E the tail factor would increase by a value of 1.0. Since the numbers of these confounding cells were not determined in exposed and sham groups the validity of ‘tail factor’ data is questionable. The results and the conclusions as presented in Diem et al. [1] and Ivancsits et al. [2,5–7] will be highly ‘cited’ by researchers (in the years to come) since they are published in peer-reviewed scientific journals. However, because of the questionable nature of the results in these reports, we believe that it is imperative for researchers and public health officials wait for the data from confirmation/replication investigations to confirm or contradict these observations and to determine whether the reported changes in ‘tail factor’ are due EMF-induced DNA damage or due to other confounding variables.

20. DNA strand breaks are not induced in human cells exposed to 2.1425 GHz band CW and W-CDMA modulated radiofrequency fields allocated to mobile radio base stations 2006

Bioelectromagnetics 2006 Jan;27(1):51-7.

From: http://www.ncbi.nlm.nih.gov/pubmed/16283663

Sakuma N, Komatsubara Y, Takeda H, Hirose H, Sekijima M, Nojima T, Miyakoshi J.

Research Division for Advanced Technology, Kashima Laboratory, Mitsubishi Chemical Safety Institute Ltd., Kamisu, Ibaraki, Japan.

Abstract

We conducted a large-scale in vitro study focused on the effects of low level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system in order to test the hypothesis that modulated RF fields may act as a DNA damaging agent. First, we evaluated the responses of human cells to microwave exposure at a specific absorption rate (SAR) of 80 mW/kg, which corresponds to the limit of the average whole body SAR for general public exposure defined as a basic restriction in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Second, we investigated whether continuous wave (CW) and Wideband Code Division Multiple Access (W-CDMA) modulated signal RF fields at 2.1425 GHz induced different levels of DNA damage. Human glioblastoma A172 cells and normal human IMR-90 fibroblasts from fetal lungs were exposed to mobile communication frequency radiation to investigate whether such exposure produced DNA strand breaks in cell culture. A172 cells were exposed to W-CDMA radiation at SARs of 80, 250, and 800 mW/kg and CW radiation at 80 mW/kg for 2 and 24 h, while IMR-90 cells were exposed to both W-CDMA and CW radiations at a SAR of 80 mW/kg for the same time periods. Under the same RF field exposure conditions, no significant differences in the DNA strand breaks were observed between the test groups exposed to W-CDMA or CW radiation and the sham exposed negative controls, as evaluated immediately after the exposure periods by alkaline comet assays. Our results confirm that low level exposures do not act as a genotoxicant up to a SAR of 800 mW/kg.

21. Lack of Direct DNA Damage in Human Blood Leukocytes and Lymphocytes After InVitro Exposure to High Power Microwave Pulses 2006

Bioelectromagnetics Volume 27, Issue 3, pages 197–203, April 2006

From: http://onlinelibrary.wiley.com/doi/10.1002/bem.20196/abstract

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Abstract

Currently, the potential genotoxicity of high power microwave pulses (HPMP) is not clear. Using the alkaline single cell gel electrophoresis assay, also known as the alkaline comet assay, we studied the effects of HPMP (8.8 GHz, 180 ns pulse width, peak power 65 kW, pulse repetition frequency 50 Hz) on DNA of human whole-blood leukocytes and isolated lymphocytes. The cell suspensions were exposed to HPMP for 40 min in a rectangular waveguide. The average SAR calculated from the temperature kinetics was

about 1.6 kW/kg (peak SAR was about 300 MW/kg). The steady-state temperature rise in the 50 ml samples exposed to HPMP was 3.5_0.1 8C. In independent experiments, we did not find any statistically significant DNA damage manifested immediately after in vitro HPMP exposure of human blood leukocytes or lymphocytes or after HPMP exposure of leukocytes subsequently incubated at 37.8C for 30 min. Our results indicate that HPMP under the given exposure conditions did not induce DNA strand breaks, alkali-labile sites, and incomplete excision repair sites, which could be detected by the alkaline comet assay.

22. Single strand DNA breaks in rat brain cells exposed to microwave radiation 2006

Mutat Res. 2006 Apr 11;596(1-2):76-80. Epub 2006 Feb 2

From: http://www.ncbi.nlm.nih.gov/pubmed/16458332

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Abstract

This investigation concerns with the effect of low intensity microwave (2.45 and 16.5 GHz, SAR 1.0 and 2.01 W/kg, respectively) radiation on developing rat brain. Wistar rats (35 days old, male, six rats in each group) were selected for this study. These animals were exposed for 35 days at the above mentioned frequencies separately in two different exposure systems. After the exposure period, the rats were sacrificed and the whole brain tissue was dissected and used for study of single strand DNA breaks by micro gel electrophoresis (comet assay). Single strand DNA breaks were measured as tail length of comet. Fifty cells from each slide and two slides per animal were observed. One-way ANOVA method was adopted for statistical analysis. This study shows that the chronic exposure to these radiations cause statistically significant ($p<0.001$) increase in DNA single strand breaks in brain cells of rat.

23. Evaluating the combinative effects on human lymphocyte DNA damage induced by Ultraviolet ray C plus 1.8 GHz microwaves using comet assay in vitro 2007

Toxicology 232 (2007) 311–316

From: http://ieee-emf.com/viewstudy.cfm?ID=1566

Wang Baohong, Jin Lifen, Li Lanjuan, Lou Jianlin, Lu Deqiang, Zheng Wei, He Jiliang

Abstract

The objective of this study was to observe whether 1.8 GHz microwaves (MW) (SAR, 3 W/kg) exposure can influence human lymphocyte DNA damage induced by ultraviolet ray C (UVC). The lymphocytes, which were from three young healthy donors, were exposed to 254nm UVC at the doses of 0.25, 0.5, 0.75, 1.0, 1.5and 2.0 Jm−2, respectively. The lymphocytes were irradiated by 1.8GHz MW (SAR, 3 W/kg) for 0, 1.5 and 4 h. The combinative exposure of UVC plus MW was conducted. The treated cells were incubated for 0, 1.5 and 4 h. Finally, comet assay was used to measure DNA damage of above treated lymphocytes. The results indicated that the difference of DNA damage induced between MW group and control group was not significant ($P > 0.05$). The MTLs induced by UVC were 1.71±0.09, 2.02±0.08, 2.27±0.17, 2.27±0.06, 2.25±0.12, 2.24±0.11_m, respectively, which were significantly higher than that (0.96±0.05_m) of control ($P < 0.01$). MTLs of some sub-groups in combinative exposure groups at 1.5-h incubation were significantly lower that those of corresponding UVC sub-groups ($P < 0.01$ or $P < 0.05$). However, MTLs of some sub-groups in combinative exposure groups at 4-h incubation were significantly higher that those of corresponding UVC sub-groups ($P < 0.01$ or $P < 0.05$). In this experiment it was found that 1.8 GHz (SAR, 3 W/kg) MW exposure for 1.5 and 4 h did not enhance significantly human lymphocyte DNA damage, but could reduce and increase DNA damage of human lymphocytes induced by UVC at 1.5-h and 4-h incubation, respectively.

24. Genotoxic effects of exposure to radiofrequency electromagnetic fields (RF-EMF) in cultured mammalian cells are not independently reproducible 2007

Mutat Res. 2007 Jan 10;626(1-2):42-7. Epub 2006 Sep 25.

From: http://www.ncbi.nlm.nih.gov/pubmed/16997616

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Abstract

Conflicting results have been published regarding the induction of genotoxic effects by exposure to radiofrequency electromagnetic fields (RF-EMF). Using the comet assay, the micronucleus test and the chromosome aberration test with human fibroblasts (ES1 cells), the EU-funded "REFLEX" project (Risk Evaluation of Potential Environmental Hazards From Low Energy Electromagnetic Field Exposure Using Sensitive in vitro Methods) reported clearly positive effects for various exposure conditions. Because of the ongoing discussion on the biological significance of the effects observed, it was the aim of the present study to independently repeat the results using the same cells, the same equipment and the same exposure conditions. We therefore exposed ES1 cells to RF-EMF (1800 MHz; SAR 2 W/kg, continuous wave with intermittent exposure) for different time periods and then performed the alkaline (pH > 13) comet assay and the micronucleus test (MNT). For both tests, clearly negative results were obtained in independently repeated experiments. We also performed these experiments with V79 cells, a sensitive Chinese hamster cell line that is frequently used in genotoxicity testing, and also did not measure any genotoxic effect in the comet assay and the MNT. Appropriate measures of quality control were considered to exclude variations in the test performance, failure of the RF-EMF exposure or an evaluation bias. The reasons for the difference between the results reported by the REFLEX project and our experiments remain unclear.

Acknowledgements
We gratefully acknowledge the excellent cooperation with Prof. F. Adlkofer (REFLEX project; VERUM foundation) and Prof. H.W. Rudiger and his co-workers (Vienna). We thank Prof. N. Kuster, Denis Spat and Albert Roman (IT'IS Foundation, Zurich) for providing us with the exposure system, for checking the function of the system and for supporting the blind evaluation of the experiments. The ES1 cells were kindly provided by Prof. Rudiger and the study was financially supported by the VERUM foundation.

25. Genetic damage in mammalian somatic cells exposed to radiofrequency radiation: a meta-analysis of data from 63 publications (1990-2005) 2008

Radiat Res. 2008 May;169(5):561-74.

From: http://www.ncbi.nlm.nih.gov/pubmed/18494173

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Abstract

During the last several decades, numerous researchers have examined the potential of in vitro and /or in vivo exposure of radiofrequency (RF) radiation to damage the genetic material in mammalian somatic cells. A meta-analysis of reported data was conducted to obtain a quantitative estimate (with 95% confidence intervals) of genotoxicity in RF-radiation-exposed cells compared with sham-exposed/unexposed control cells. The extent of genotoxicity was assessed for various end points, including single- and double-strand breaks in the DNA, incidence of chromosomal aberrations, micronuclei and sister chromatid exchanges. Among the several variables in the experimental protocols used in individual investigations, the influence of three specific variables related to RF-radiation exposure characteristics was examined in the meta-analysis: frequency, specific absorption rate, and exposure as continuous-wave, pulsed-wave and occupationally exposed/cell phone users. The overall data indicated that (1) the difference between RF-radiation exposure was small with few exceptions; (2) at certain RF radiation exposure conditions, there were statistically significant increases in genotoxicity for some end points; and (3) the mean indices for chromosomal aberrations and micronuclei in RF-radiation -exposed and sham-/unexposed controls were within the spontaneous levels reported in the historical database. Considerable evidence for publication bias was found in the meta-analysis.

26. Radiofrequency electromagnetic fields (UMTS, 1950 MHz) induces genotoxic effects in vitro in human fibroblasts but not in lymphocytes 2008

Int Arch Occup Environ Health 81:755–767; 2008

From: http://www.springerlink.com/content/222060761287780q/

Schwarz C, Kratochvil E, Pilger A, Kuster N, Adlkofer F, Rudiger H.

Objective

Universal Mobile Telecommunication System (UMTS) was recently introduced as the third generation mobile communication standard in Europe. This was done without any information on biological effects and genotoxic properties of these particular high-frequency electromagnetic fields. This is discomforting, because genotoxic effects of the second generation standard Global System for Mobile Communication have been reported after exposure of human cells in vitro.

Methods

Human cultured fibroblasts of three different donors and three different short-term human lymphocyte cultures were exposed to 1,950 MHz UMTS below the specific absorption rate (SAR) safety limit of 2 W/kg. The alkaline comet assay and the micronucleus assay

were used to ascertain dose and time-dependent genotoxic effects. Five hundred cells per slide were visually evaluated in the comet assay and comet tail factor (CTF) was calculated. In the micronucleus assay 1,000 binucleated cells were evaluated per assay. The origin of the micronuclei was determined by fluorescence labeled anticentromere antibodies. All evaluations were performed under blinded conditions.

Results

UMTS exposure increased the CTF and induced centromere-negative micronuclei (MN) in human cultured fibroblasts in a dose and time-dependent way. Incubation for 24 h at a SAR of 0.05 W/kg generated a statistically significant rise in both CTF and MN ($P = 0.02$). At a SAR of 0.1 W/kg the CTF was significantly increased after 8 h of incubation ($P = 0.02$), the number of MN after 12 h ($P = 0.02$). No UMTS effect was obtained with lymphocytes, either unstimulated or stimulated with Phytohemagglutinin.

Conclusion

UMTS exposure may cause genetic alterations in some but not in all human cells in vitro.

27. In vitro assessment of clastogenicity of mobile-phone radiation (835 MHz) using the alkaline comet assay and chromosomal aberation test. 2008

Environ Toxicol. 2008 Jun;23(3):319-27.

From: http://www.ncbi.nlm.nih.gov/pubmed/18214898

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Abstract

Recently we demonstrated that 835-MHz radiofrequency radiation electromagnetic fields (RF-EMF) neither affected the reverse mutation frequency nor accelerated DNA degradation in vitro. Here, two kinds of cytogenetic endpoints were further investigated on mammalian cells exposed to 835-MHz RF-EMF (the most widely used communication frequency band in Korean CDMA mobile phone networks) alone and in combination with model clastogens: in vitro alkaline comet assay and in vitro chromosome aberration (CA) test. No direct cytogenetic effect of 835-MHz RF-EMF was found in the in vitro CA test. The combined exposure of the cells to RF-EMF in the presence of ethylmethanesulfonate (EMS) revealed a weak and insignificant cytogenetic effect when compared to cells exposed to EMS alone in CA test. Also, the comet assay results to evaluate the ability of RF-EMF alone to damage DNA were nearly negative, although showing a small increase in tail moment. However, the applied RF-EMF had

potentiation effect in comet assay when administered in combination with model clastogens (cyclophosphamide or 4-nitroquinoline 1-oxide). Thus, our results imply that we cannot confidently exclude any possibility of an increased risk of genetic damage, with important implications for the possible health effects of exposure to 835-MHz electromagnetic fields.

28. Critical comments on DNA breakage by mobile-phone electromagnetic fields [Diem et al., Mutat. Res. 583 (2005) 178-183] 2010

Mutat Res. 2010 Mar 29;697(1-2):60-5. Epub 2010 Jan 25.

From: http://www.ncbi.nlm.nih.gov/pubmed/20100594

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Comment in:

- Mutat Res. 2010 Mar 29;697(1-2):66-7.

Comment on:

- Mutat Res. 2005 Jun 6;583(2):178-83.

Abstract

In a publication that appeared in 2005 (Diem et al., Mutat. Res. 583:178-183) harmful effects (DNA breakage) were reported to occur in rat and human cells after exposure to mobile-phone electromagnetic fields. The extremely low standard deviations in this paper, and in another publication by the same group of authors, prompted Vijayalaxmi to write a critical comment [Mutat. Res. 603 (2006) 104-106] . An investigation by the Medical University of Vienna (Austria) was initiated by a letter by the first author of the present paper, based on the data contained in the reply by the authors [Rüdiger et al., Mutat. Res. 603 (2006) 107-109]. The University published three press releases, stating that "the data were not measured experimentally, but fabricated" and that the Mutation Research paper and another, published by the International Archives of Occupational and Environmental Health (IAOEH) in 2008, should be retracted. So far, neither of these papers has been retracted. Only a Letter of Concern by the Editors of IAOEH, and an Editorial by Mutation Research were published. Here we describe the statistical methods used to identify the evidence of data fabrication. The major point is the small variation in

the reported data, which is below the theoretical lower limit derived from multinomial distributions and also lower than those derived from detailed simulations. Another reason for doubt was the highly significant non-equal distribution of last digits, a known hint towards data fabrication. In view of the results of the University's investigation and the evidence presented in this paper, the Diem et al. (2005) publication should be retracted, with or without the authors' agreement.

29. Radiofrequency Studies on Tumorigenesis and the Blood-Brain Barrier in Lab Animals Support the Conclusion of No Adverse Effects without Significant Tissue Temperature Increase

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Abstract

This paper summarizes the weight of scientific evidence on whether or not exposure of laboratory animals to radiofrequency (RF) energy a) causes or promotes tumor development and b) affects the integrity of the blood-brain barrier (BBB). Forty-four studies of tumorigenesis were identified. In addition to the studies of spontaneous tumorigenesis in animals exposed to RF energy alone, 21 of the 44 studies investigated tumor promotion in animals exposed to RF energy in combination with chemicals [e.g., ethylnitrosurea (ENU) and 7,12-dimethylbenz[a)anthracene (DMBA») and physical agents (e.g., x-rays and ultraviolet radiation) known to cause cancer. Evaluation of the results in all 44 studies on tumorigenesis showed no adverse effect of RF exposure up to two years in duration at dose rates up to 4 W/kg (10 times greater than the occupational safety limit) on carcinogenic processes (initiation, promotion and co-promotion). Other information in these studies on survival and body mass provides supporting evidence for the conclusion that RF exposure does not affect tumor development because a) 26 of 27 studies since 1983 reported no significant change on survival and b) all 27 studies reporting body mass observed no significant change in this health indicator. The weight of evidence of 44 animal tumorigenic studies supports the conclusion that RF exposure within current internationally accepted limits, when given alone or in combination with carcinogens, is unlikely to affect tumor development in human beings. Furthermore, the results showing a lack of RF effects on tumorigenesis, survival and body mass in live animals offer a strong challenge to studies reporting potential genotoxic and other health effects based on research with cells in culture and other biological samples exposed in vitro to RF energy. Another area of research has focused on whether or not RF exposure

could affect the integrity of the blood-brain barrier (BBB) that protects the brain from potentially toxic molecules in the blood. A number of laboratories have confirmed that the permeability of the BBB can be affected if the temperature of the brain is increased significantly. The effect is a temperature effect because it does not matter whether the effect on the BBB was caused by exposing the animal to heated air, heated water or RF energy. Reports in the 1970s and more recent reports of changes in BBB permeability following exposure to levels of RF energy that would not significantly increase the brain temperature have failed the test of independent confirmation.