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The rate of elimination of chromosomal aberrations after accidental exposure to microwave radiation

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Abstract

Analysis of structural chromosome aberrations was performed in a group of radar station personnel who were engaged in repairing radar devices a couple of days earlier. Test results showed a major decline from the values recorded by regular mutagenic monitoring in terms of a significantly increased number of chromosome breaks, acentric fragments, dicentric and polycentric chromosomes with accompanying fragments, ring chromosomes and chromatid interchange. Multiply repeated mutagenic testing demonstrated for all subjects a fall in the total number of chromosome aberrations as a function of time. During a 30-week-long follow-up study a decrease in the total number of chromosome aberrations was observed. In the same period the presence of unstable aberrations such as dicentrics and ring chromosomes persisted, together with a relatively unchanged incidence of stable aberrations.

INTRODUCTION

The presence of chromosomal aberrations is reliable evidence of damaged cell genomes in *in vivo* and *in vitro* environmental mutagenic studies [1,2]. Therefore, the analysis of chromosomal aberrations is applicable to the estimation of persistence of induced chromosomal aberrations in human peripheral blood lymphocytes. Follow-up is possible at various time intervals after occupational or accidental exposure to ionizing. Recently, the effects of other mutagenes such as microwave radiation [3–6] have been studied.

The results of cytogenetic studies on the effects of microwave radiations in causing chromosomal aberrations have been obtained mainly from *in vivo* culture

of animal and human cells exposed under certain conditions of exposure in a very wide range of frequencies and densities [7-11].

As the number of microwave radiation sources in the world increases, so the levels of radiation exposure of certain populations increase. Very little is known about the conditions of exposure of populations that were acutely or chronically irradiated during their occupational activity [12,13], and the existing data deal mainly with secondary changes caused by dysfunction of some organs or organic systems [14,15]. For this reason research into the mutagenic changes of somatic cells in subjects occupationally exposed to microwave radiation, as well as the persistence of the structural damage to chromosomes so induced, together with the follow-up of the health condition of subjects has been given special attention.

This paper presents cytogenetic examinations carried out in subjects accidentally exposed to microwave radiation. Structural changes were followed up over the course of 30 weeks after the "accident", with the purpose of demonstrating the persistence of such changes after acute exposure.

SUBJECTS AND METHODS

Six air traffic control workers who were exposed daily to microwave radiation were examined. They had been occupationally exposed to pulsed microwaves for 12-20 years (average = 16 years; standard deviation (SD) ± 2.4). Microwave power density at different work places was measured with a Raham model 4A (General Microwave Corporation, Farmingdale, NY). The subjects remained at the work places every other day for 12 h in a microwave field of $10 \mu\text{gW}/\text{cm}^2$ - $20 \text{mW}/\text{cm}^2$ with a frequency range of 1250-1350 MHz. The average age of the workers was 40.6 years (range = 38-45 years, SD ± 2.1). The results of chromosomal aberration analysis for these subjects in the period 1984-1990 showed no increase in comparison with controls.

Before being examined for this study, the subjects had repaired radar devices so that they had been exposed to microwave radiation of unknown intensity. We assume that it was higher than their average daily exposure.

After the first sampling of the six subjects mutagenic testing was carried out repeatedly in order to complete the analysis of structural chromosomal aberrations. Time intervals ranged from 3 to 30 weeks.

For all subjects mutagenic tests were performed in vitro using lymphocyte culture. Conventional methods for preparation and analysis of chromosomes for structural aberrations were used [16]. At various intervals after the "accident" heparinized samples of 5 ml venous blood were incubated at 37°C in 5 ml of F-10 medium (Gibco) supplemented with bovine serum (20%) and phytohaemagglutinin (Wellcome) as a mutagenic stimulator. During 45 h of incubation 0.004% colchicine (0.5 ml) was added to the culture. The cells were harvested at 48 h. After hypotonic treatment with KCl (0.075 M) the cells were fixed in methanol:acetic acid (3:1), spread on clear slides, left to dry and stained with 5% Giemsa solution. 200 metaphases were analysed per testing and subject. Aberrations were classified

TABLE 1

Type and percentage of chromosomal aberrations after "accidental" exposure to high power density of pulsed microwave radiation

Subject	Date of examination	Chromatid breaks	Chromosome breaks	Acentrics	Dicentrics	Rings	Chromatid interchange	Aberrations /%
1	18.11.1990	2	1	2	1			3.0
	5.12.1990		1	1	1			1.5
2	6.12.1990		4	8	4	1		8.5
	25.02.1991	4	1	3	1			4.5
3	6.12.1990		3	10	3			8.5
	26.02.1991	4	3	3	2			6.0
4	20.12.1990		1	2		1		2.0
	16.01.1991		3	5	1	1		5.0
5	11.12.1990		6	48	9	3		33.0
	14.02.1991	1	4	31	6	2		22.0
	13.03.1991	4	7	18	6	1		18.0
	17.04.1991	6	6	6			1	9.5
	22.05.1991	3	4	6	2			7.5
	2.05.1991	1		5	1			3.5
6	20.12.1990		4	2	1			3.5
	30.01.1991		2	1		1		2.0

as acentric fragments, dicentrics, ring chromosomes, chromatid interchange, and chromosomal and chromatid breaks. The results are shown in Table 1.

RESULTS

In this study, subjects who worked daily in a zone of microwave radiation and who participated in the repairing of radar devices, frequency 1250–1350 MHz and radiated pulsed power 100 kW, were followed up.

Table 1 shows the results of analysis of structural chromosomal aberrations in the subjects who, shortly before testing, were engaged in servicing radar equipment, and from 3 to 30 weeks after the first sampling.

Results of chromosomal aberration analysis of subjects before the repairing of radar devices showed only acentric fragments, chromatid and chromosome breaks which did not exceed 0.5%–2.5% (Fig. 1(A)). All subjects showed a significantly increased number of chromosome breaks, acentric fragments, dicentric and polycentric chromosomes with the accompanying fragments, ring chromosomes and chromatid interchange. The total number of aberrations for the "accidentally" exposed group ranges from 3% to 33%, with the existence of a great number of unstable aberrations such as dicentrics and ring chromosomes (Fig. 1(B)).

The analysis of structural chromosomal aberrations was repeated with all accidentally exposed individuals at various time intervals over 30 weeks. The

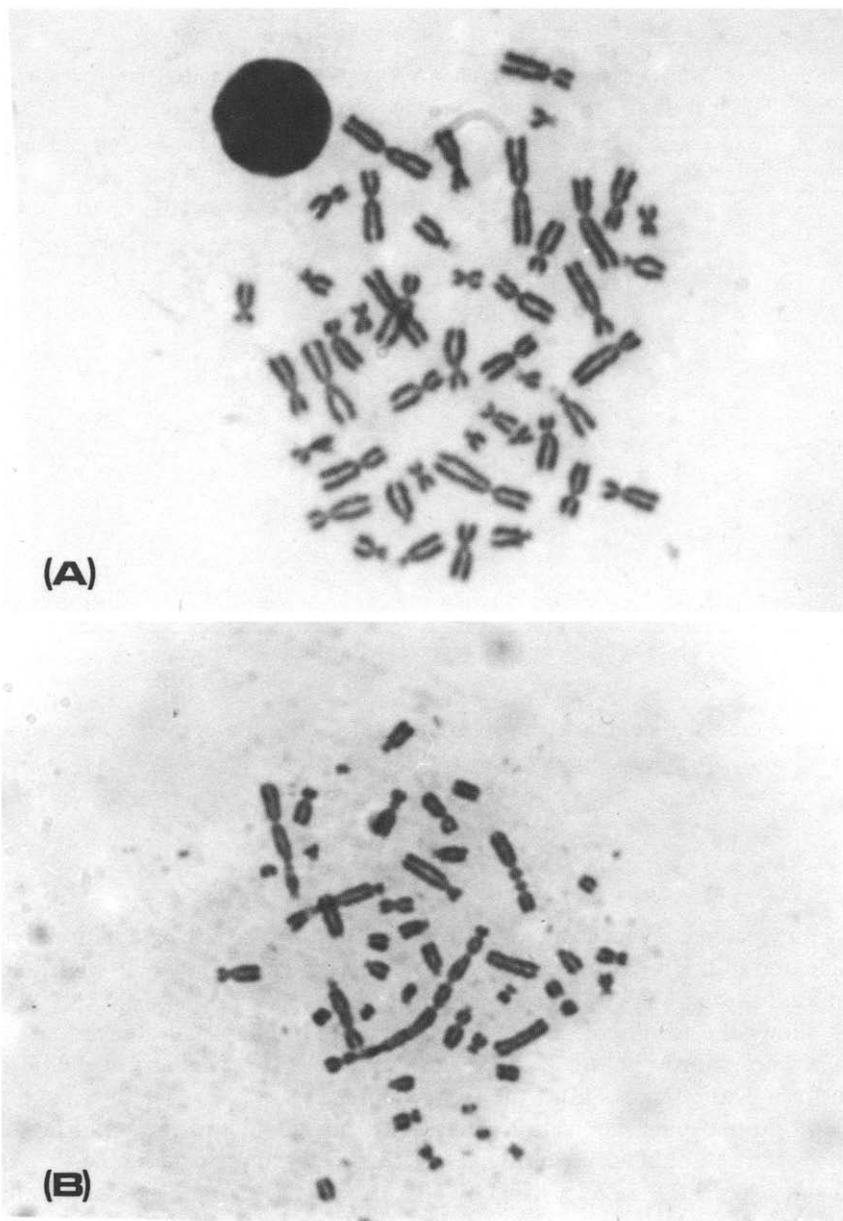


Fig. 1. Metaphase of analysed subject (A) before and (B) after "accidental" exposure to microwave radiation.

results show a decrease in the total of chromosomal aberrations 30 days after the first sampling, with dicentric and ring chromosomes still present.

From Fig. 2 it can be concluded that the results of repeated examinations of

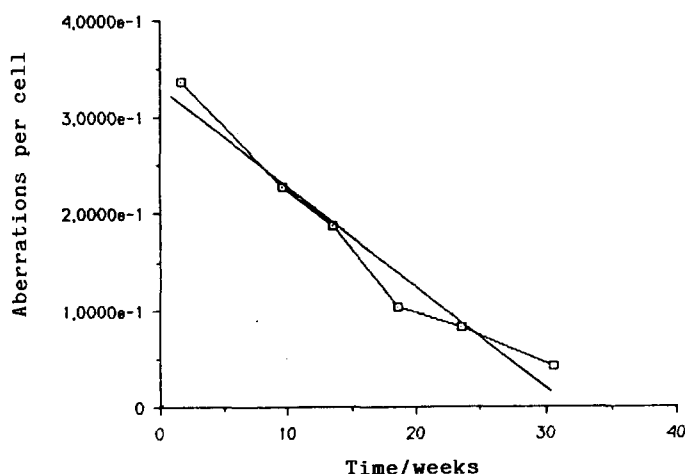


Fig. 2. The time-dependent decrease in the number of chromosomal aberrations for subjects with extremely high numbers of chromosomal impairments. $y = 0.318 - 0.010x$, $R = 0.98$.

individuals with a large number of chromosomal aberrations show a decrease in the total number of aberrations from 33% to 3.5% after 30 weeks of follow-up, but with unstable aberrations still present.

DISCUSSION

Until recently the primary effect of microwave radiation was believed to be thermic. Only high-intensity radiation was believed to be able to cause certain changes in biological systems [17,18]. Biological effects of microwave radiation are now known to manifest as physical and chemical changes, both in the tissue and in molecules, causing the reaction of the whole organism. These are mostly secondary changes caused by the non-functionality of particular organs or organic systems [14].

However, studies attracting growing attention are those which indicate certain non-thermal effects of microwave radiation [10,18], identifiable because of their biological consequences (headache, fatigue, memory loss, cardiovascular and various other changes). These effects appear after both chronic and acute occupational exposure [14,19]. The results of our earlier study, as well as the results of this work, show that the subjects exposed to microwave radiation show a series of subjective symptoms such as fatigue, neurasthenic conditions, headache and others [13]. Subjective difficulties such as headache and exhaustion, as well as appetite loss, dizziness and emotional instability have been described by other authors [19,20].

We still have very limited information about the effects of microwave radiation on DNA molecular structure, the consequences manifested as chromosomal aber-

rations or other cytological damage [10,11,18,21]. It is assumed that such data would be of special interest to occupationally exposed populations. In the absence of physical measurements the analysis of chromosome aberrations is valuable proof for the existence of changes in cell genomes, caused by some mutagenic agent.

Our investigations show that the group which worked on repairing radar devices, without personal protection, have definitely been exposed to a high, albeit unknown, intensity of microwave radiation. As a result of this exposure there is a presence of as much as 33% of the total number of chromosomal aberrations in one examined subject. As the subjects in this study are controls to themselves, this high percentage of total chromosomal aberrations, occurring after working on radar devices, points to such exposure as a high occupational risk.

In all accidentally exposed subjects repeated mutagenic tests show the decrease in total chromosomal aberrations to be in correlation with the results given by Leonard et al. [22] in the analysis of accidentally irradiated subjects. The decrease in the total chromosomal aberrations found in the subjects of our study can be explained by *in vivo* elimination of chromosomally altered lymphocytes. This phenomenon is present in all cytogenetic analyses which have been conducted on several occasions after the irradiation.

That the number of chromosomal aberrations caused by microwave radiation decreased during the 30 weeks is noticeable for the subject with an extremely high number of chromosomal aberrations (Fig. 2). It is observed that a decrease in total chromosomal aberrations is followed by a decrease in unstable aberrations. Aberrations such as dicentrics and ring chromosomes are associated with the loss of functional processes within the cell, so that these cells are quickly eliminated from circulation.

Cells with stable aberrations retain the majority of cell functions so that the number of such cells persists almost unchanged, even 6 months after "accidental" exposure. A similar persistence of stable aberrations remaining largely unchanged over a period from 99 to 251 months after accidental irradiation by gamma rays is described by Leonard et al. [22].

The possible mutagenic changes of somatic cells in the subjects of this study should be analysed from the point of view of microwave radiation effects on the molecular structure of DNA. Recent studies suggest that microwave radiation could result in single-strand and double-strand breaks of the DNA molecule [23], as well as in changes of the deoxyribonucleic acid synthesis and structure [10].

According to other authors, consequences of these mutations are related to neoplasms. Out of 29 epidemiological studies published in the last decade, 22 suggest a relationship between various neoplasms and exposure to electromagnetic fields [24].

In the case of populations occupationally exposed to microwaves and not using protective suits, biodosimetry is the only suitable method for providing evidence of exposure because personal dosimeters for microwave radiation have not yet been developed.

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