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CHROMOSOME BREAKAGE AND SISTER CHROMATID EXCHANGE ANALYSIS IN COMPUTER OPERATORS

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Abstract

Chromosome breakage analysis with Mitomycin C (MMC) and sister chromatid exchanges (SCE) were obtained on 10 computer operators with computer exposure for a minimum of 3 hours per day for 4 years and 10 control subjects matched for age and personal lifestyle. No difference was found between the two groups in the total number of chromatid and chromosome aberrations in cells grown at 48 and/or 96 hours in Mitomycin C (20 or 50 ng/ml-final concentration). The average number of SCE per cell in approximately 30 cells from each person was 6.4 ± 1.1 (mean $\pm$ standard deviation) for the computer operators and 9.2 ± 1.6 for the controls. This difference was significant ($p < .001$). The replicative index was significantly higher ($p < .01$) in computer operators than in control subjects. The number of SCE appeared not to be influenced by the years of computer exposure. Additional studies with larger sample sizes will be needed to identify if significant differences exist in cell kinetics and sister chromatid exchanges in individuals employed as computer operators.

Keywords

computer usage; sister chromatid exchanges; chromosome breakage

INTRODUCTION

There is a concern in the scientific and public communities about deleterious effects of electromagnetic radiation in humans.¹ A possible source of electromagnetic radiation exposure may be personal computers. It is estimated that there are over 10 million computer terminals in active use in this country.² Although the amount of radiation emitted by the majority of cathode ray tubes found in personal computers has been below accepted radiation levels, increased usage and possible adverse effects of long-term exposure of electromagnetic radiation on biological systems requires further studies. Therefore, we have undertaken a chromosome breakage analysis with Mitomycin C, an alkylating agent that induces chromosome damage, and sister chromatid exchanges, an indicator of early chromosome changes, on ten individuals employed as personal computer operators and ten age-matched control subjects.

MATERIALS AND METHODS

Subjects

Our study consisted of ten individuals employed as personal computer operators (4 males and 6 females with an age range from 24 to 41 years and an average age of 31.8 years) and control subjects matched for age (± 5 years). The average personal computer usage for the ten individuals was 5 hours per day for 5.9 years (range 3 hours a day for 4 years to 9 hours a day for 3.5 years). All individuals denied a history of significant illnesses, medications, recent x-ray exposure, alcohol consumption and smoking. Approximately 10 ml of blood was obtained from each patient and an age-matched control subject. All blood was cultured under the same conditions. Student t-tests were used throughout the study for statistical analysis.

Mitomycin C (MMC)

Age-matched blood samples from ten personal computer operators and ten control subjects were collected. Peripheral blood (0.5 ml) was added to 10 ml of RPMI 1640 supplemented with 15% fetal calf serum, penicillin (20 U/ml), streptomycin (20 ug/ml), phytohemagglutinin, and 20 and/or 50 ng/ml mitomycin C (MMC) as previously described.^{3,4,5} The cultures were incubated at 37° C for either 48 or 96 hours. Forty-five minutes before harvest, colcemid (0.2 ug/ml-final concentration) was added. The cells were then treated with hypotonic saline (0.075M KC1) and fixed in 3:1 methanol-acetic acid. Conventional air dried slides were prepared and stained with Giemsa. Approximately 100 metaphase cells were scored from the 96 hour and 50 cells from the 48 hour cultures. Diploid, or near diploid (44 chromosomes), cells were analyzed for chromosome breakage. The following aberrations were observed: 1) chromatid type, including chromatid breaks, gaps, and exchange figures (e.g. triradials and quadriradials); and 2) chromosome type (dicentrics, rings, double minutes, fragments, and markers).

Sister Chromatid Exchanges (SCE)

Sister chromatid exchanges (SCE) were analyzed from ten personal computer operators and ten control subjects matched for age. Peripheral blood (0.5ml) was added to 10 ml of RPMI 1640 supplemented with 15% fetal calf serum, penicillin, (20 U/ml), streptomycin (20 ug/ml), phytohemagglutinin, and 20 uM 5-bromodeoxy-uridine and the cultures were incubated at 37° C in the dark, as previously described.⁵ Colcemid (0.2 ug/ml-final concentration) was added after 69 hours of incubation and the cells harvested at 72 hours, then treated with hypotonic saline (0.075M KC1) and fixed in 3:1 methanol-acetic acid. The chromosomes were stained with the FPG technique.⁶ The percentage of first, second and third divisions were recorded from a minimum of 100 cells. The number of SCE from approximately 30 analyzable metaphases were also recorded. The average number of exchanges per cell was recorded and the replicative index was calculated from the percentage of cells in first, second and third divisions.⁷

RESULTS

Mitomycin C (MMC)

Table 1 and 2 summarizes the results of the Mitomycin C (MMC) studies from the computer operators and age-matched control subjects grown in 20 ng/ml MMC for 48 and 96 hours, respectively. The average frequency and standard deviation for total chromosome and chromatid aberrations per 50 cells grown in 20 ng/ml MMC for 48 hours was 2.4 ± 1.5 for the computer operators and 3.0 ± 2.4 for the control subjects. The average frequency and standard deviation for total chromosome and chromatid aberrations per 100 cells grown in 20 ng/ml MMC for 96 hours was 5.7 ± 1.9 for the computer operators and 6.7 ± 2.9 for the control subjects. Therefore, there were no differences in the number of aberrations observed at 48 or 96 hours between the controls and computer operators. Chromosome data from nine computer operators and nine age-matched controls grown in 50 ng/ml MMC for 48 hours also showed no significant difference in the number of aberrations between the two groups.

Sister Chromatid Exchanges (SCE)

Table 3 includes a summary of the SCE results. The average SCE frequency and standard deviation for the computer operators and control subjects were 6.4 ± 1.1 and 9.2 ± 1.6 , respectively. This difference in the number of SCE observed between the two groups was significant ($p < .001$). The average replicative index for the computer operators and control subjects were 2.05 and 1.79, respectively. This difference in replicative indices was also significant ($p < .01$).

DISCUSSION

Sister chromatid exchanges (SCE) and chromosome breakage studies with Mitomycin C have been used as indicators of genetic damage to investigate the effect that factors in the environment, such as cigarette smoking,^{8,9,10} viruses,¹¹ alcohol consumption,¹² and chemotherapeutic agents,^{13,14,15} may have on genetic stability. Several of these environmental agents are known to cause chromosome changes. Therefore, we have undertaken our investigation of computer usage as a potential source of electromagnetic radiation on the genetic material of computer operators. It is generally thought that the level of radiation emitted by computer terminals is within accepted guidelines,¹⁶ although the effects of long term exposure on genetic information is not known.

Our chromosome breakage analysis with Mitomycin C in computer operators and control subjects matched for age and personal lifestyle does not suggest genetic damage. However, the frequency of SCE and the cell replicative indices were different in the two groups. In the present study the computer operators had a lower frequency of SCE and a higher average replicative index than controls. It has been suggested that SCE per cell may be negatively correlated with the replicative index,^{17,18} as found in our SCE study. Higher replicative indices suggest a decreased number of first division cells and/or an increased number of third division cells.⁷

Low SCE rates were also recently reported in Seventh-Day Adventists¹⁹ This was attributed to the personal lifestyles (vegetarian diet, no smoking, coffee, tea or alcohol consumption) and lower risk of cancer in Seventh-Day Adventists.

Low SCE frequencies were also found in lymphocytes of workers exposed to benzene.⁷ These investigators found a decrease in the SCE frequency which was dependent on the amount of past exposure to benzene. They proposed that certain chemicals such as benzene at relatively low levels may affect DNA repair at the replication point and inhibit SCE formation. Conversely, high levels of benzene may induce DNA damage and increase the SCE frequency. They also speculated that the B and T lymphocyte ratio may play a role in the SCE frequency. B lymphocytes have a lower frequency of SCE than T lymphocytes.¹⁷

The personal lifestyle of the computer operators in our study did not differ from the control subjects. The years of computer exposure also did not appear to influence the SCE frequency. The majority of our individuals were analysed for SCE by the same observer, therefore interpretive errors should not account for the difference in SCE frequency between the two groups. Therefore, the lower SCE frequencies and higher replicative indices in the computer operators is of interest in view of normal chromosome breakage analysis with Mitomycin C. Additional cytogenetic studies with larger sample sizes will be needed to determine if early chromatid changes identified by SCE or alteration in cell kinetics exists in individuals employed as computer operators.

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TABLE 1

Percentage of Cells With Aberrations Treated With 20 ng/ml Mitomycin C for 48 Hours

Subject Group	Chromatid and Chromosome Aberrations	Chromatid Aberrations	Chromosome Aberrations
Operator (n = 9)	5.0	4.3	0.7
Control (n = 9)	5.6	4.7	1.0
t test	-0.55	-0.38	-0.80

not significant ($p > .05$)

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TABLE 2

Percentage of Cells With Aberrations Treated With 20 ng/ml Mitomycin C for 48 Hours

Subject Group	Chromatid and Chromosome Aberrations	Chromatid Aberrations	Chromosome Aberrations
Operator (n = 9)	5.7	4.9	0.8
Control (n = 9)	7.1	5.8	1.2
t test	-0.91	-0.63	-0.71

not significant ($p > .05$)

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TABLE 3

Frequency of SCE From Control and Computer Operators

Subject Group	Number	Age		Sex	Average Number of SCE (group mean $\pm$ SD range)		Total No. of Cells Analyzed	Repli- cative Index **
		Mean	Range		Per Cell*	Per Individual		
Operator	10	31.8	24–41	4/6	6.4 $\pm$ 1.1	5.4–8.5	294	2.05
Control	10	33.9	23–39	4/6	9.2 $\pm$ 1.6	6.6–12.4	302	1.79

* significant difference ($p < .001$) between the two groups.** significant difference ($p < .01$) between the two groups.