EVALUATION OF CYTOGENETIC DAMAGE IN NUCLEAR MEDICINE PERSONNEL OCCUPATIONALLY EXPOSED TO LOW-LEVEL IONISING RADIATION

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INTRODUCTION

Occupational exposure in nuclear medicine departments is mainly related to low doses of particular ionising emissions from radioactive isotopes such as ^{99}mTc, ^{131}I, ^{32}P, ^{67}Ga, ^{111}In, ^{201}Tl, ^{59}Fe, ^{57}Co, ^{51}Cr, ^{192}Ir [1]. The source of this exposure consists of two distinct types: (i) exposure to photon radiation that is emitted by the radioactivity retained by the patient that has not been absorbed within the patient. (ii) contact with radioactive secretions, excretions or tissue from the patient [2]. Contrary to the patients, medical staff is usually exposed to much lower doses, but for a longer period of time. All professional and technical staff in nuclear medical facilities are responsible for maintaining radiation exposure at ALARA (as low as reasonably achievable) levels. However, due to the ability of ionising radiation to induce cellular damage, there is some level of risk for the development of genetic damage after radiation exposure. The most fully developed biological indicators of ionising radiation exposure are unstable chromosomal aberrations (in particularly dicentrics) that can be detected in samples of peripheral blood lymphocytes [3,4]. This methodology usually complements data obtained by physical dosimetry and is routinely used whenever the individual dosimeter shows an exposure to penetrating radiation above its limit of detection. One of the advantages of cytogenetic dosimetry is that this biological dosimeter can be assessed at any moment, unlike physical dosimeters that are not always present on the subject [5].

The aim of the present study was to provide data on the genetic hazards due to the occupational exposure to low doses of ionising radiation in nuclear medicine departments by cytogenetic biodosimetry using the chromosome aberration test.

MATERIAL AND METHODS

The population under study was composed of 120 subjects: 60 of them had been occupationally exposed to low-level ionising radiation and 60 were unexposed control subjects. Exposed population was composed of 37 female and 23 male subjects employed in the nuclear medicine departments, exposed to particulate emissions from different radionuclides (most frequently ^{131}I and ^{99}mTc). The average age of the subjects was 42.5 years (range: 26-59 years). All exposed

subjects completed a standardised questionnaire in which personal data, working activities, type and duration of occupational exposure at the time of the study, and information on exposure to possible confounding factors were recorded. Twenty exposed subjects were regular smokers (12 female and 8 male subjects), and 40 of them were non-smokers (25 female and 15 male subjects). Mean duration of their occupational exposure at the time of blood sampling was 15.8 years (range: 1-39 years). All of them wore personal dosimeters. The effective dose received during one month before blood sampling was 196 μSv per exposed subject (range: 0-1401 μSv). The highest dose was recorded among technologists (305 μSv per subject; range: 0-1401 μSv), followed by cleaners (217 μSv per subject; range: 0-1020 μSv), engineers (149 μSv per subject; range: 0-360 μSv), nurses (64 μSv per subject; range: 0-270 μSv) and physicians (56 μSv per subject; range: 0-500 μSv). The control population was composed of 60 matched blood donors (37 female and 23 male subjects). They were chosen among healthy students and administrative employees. The average age of the control subjects was 41.8 (range: 25-59 years). 20 of them were regular smokers (12 female and 8 male subjects), while 40 of them were non-smokers (26 female and 14 male subjects). Peripheral blood samples were collected by venipuncture into heparinised tubes (Becton Dickinson, USA). The chromosome aberration test was performed in agreement with current IAEA guidelines [6]. Two hundred metaphases per subject were analysed for chromosomal aberrations. Total numbers and types of aberrations, as well as the percentage of aberrant cells per each subject were evaluated. Statistical analyses were carried out using Statistica software (StatSoft, Tulsa, USA). Multiple comparisons between groups were done by means of multifactor ANOVA on transformed data. Post-hoc analysis of differences was done by Scheffé test. The level of statistical significance was set at $p < 0.05$. The correlations between confounding factors and the parameters studied were also determined using Pearson's correlation matrices.

RESULTS

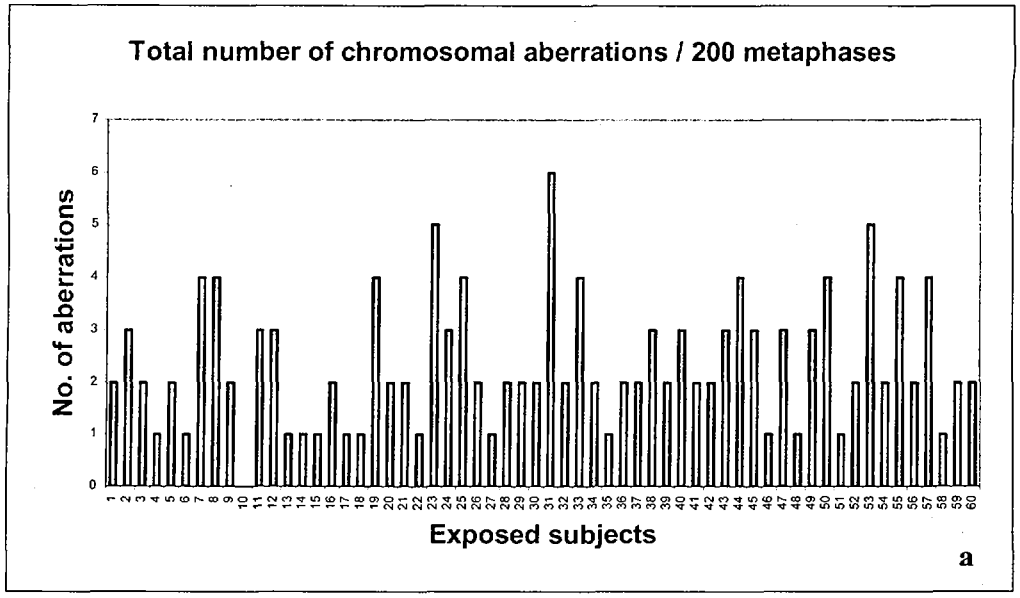
Individual results on the frequencies of chromosome aberrations (CA) recorded in peripheral blood lymphocytes of occupationally exposed and control subjects have been displayed on Figure 1 (a,b). Table 1 reports group mean frequencies of CA recorded among control and exposed subgroups.

There was a statistically significant difference between the mean frequencies of CA in exposed medical workers (2.37 ± 0.16 CA per 200 cells) and the controls (0.85 ± 0.09 CA per 200 cells) ($p<0.01$, ANOVA). Total percentage of aberrant cells was also significantly higher in exposed subjects (1.15 ± 0.08), compared to control population studied (0.23 ± 0.06). Among the exposed group, marked inter-individual variations in aberration types were observed. Control subjects, on the other hand, had more homogenous distribution of CA in their peripheral blood lymphocytes. Increased incidence of chromatid breaks was determined as a mean

frequency of 1.40 ± 0.30 per 200 cells in exposed subjects, while controls had 0.55 ± 0.08 chromatid breaks per 200 cells. The chromosome breaks were determined with a mean frequency of 0.33 ± 0.07 per 200 cells in exposed subjects, while controls had 0.07 ± 0.03 chromosome breaks per 200 cells. The mean yield of acentric fragments was 0.60 ± 0.09 per 200 cells in exposed subjects, while controls had 0.23 ± 0.06 acentric fragments per 200 cells. Dicentrics were found only in two exposed technologists, while controls had no dicentrics at all. The mean yield of dicentric chromosomes in exposed subjects was 0.03 ± 0.02 per 200 cells. The frequencies of chromosome aberrations were clearly enhanced in all exposed subjects. All categories of aberrations were found, but without significant interaction between aberration type, gender, age and smoking habits. It should be stressed that between various occupations no statistically significant differences in mean frequencies of chromosome aberrations were found. Furthermore, no correlation was found between occupations, the time of exposure, whole-body radiation exposure records and the frequency of CA in individual cases. However, significant differences regarding to total number of CA recorded were seen between smoking (1.20 ± 0.19 CA / 200 cells) and non-smoking subpopulations (0.68 ± 0.10 CA / 200 cells) from the control.

CONCLUSION

In present study a biomarker of effect (CA test) was used to evaluate initial and residual lesions (unrepaired or erroneously repaired) in lymphocytes of nuclear medicine workers. Despite of their limitations, our results indicate the possibility of genotoxic implications resulting from the occupational exposure to chronic low doses of ionising radiation in nuclear medicine departments. Staff from many different specialties contribute to the work in nuclear medicine. Because specialized workers often tend to perform the same tasks, it is quite possible that some of them would exhibit higher levels of DNA damage. Therefore, nuclear medicine physicians with higher percentage of CA, probably were involved in some specific procedures that could entail higher levels of exposures or they had repetitious high exposures. The results point to the significance of biological indicators providing information on the actual risk to the radiation exposed individuals, as such data are lacking from physical dosimetry in many cases. An important advantage of biomarkers studied is that the individual radiation damage is measured which includes the variability of individual radiosensitivity. According to our results, CA test is sensitive biomarker that can be used as additional complement to physical dosimetry in regular health surveillances of occupationally exposed radiation workers.



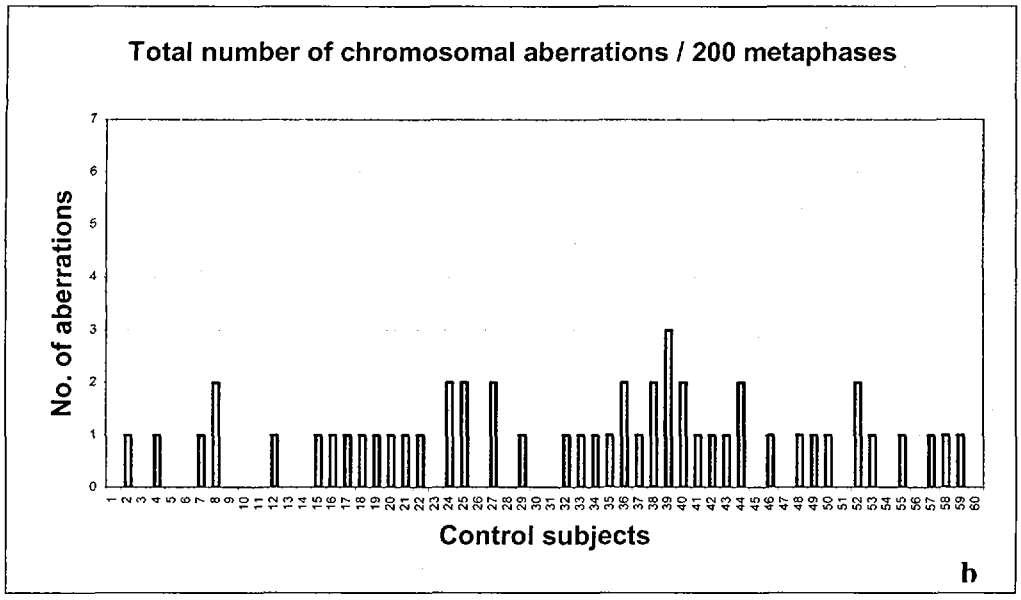


Figure 1. Individual results of the analysis of chromosomal aberrations in exposed nuclear medicine personnel (a) and control subjects (b). Exposed subjects are numbered as follows: physicians (1-12), technologists (13-38), nurses (39-45), engineers (46-53), cleaners (54-60).

Table 1. Results of the the analysis of structural chromosomal aberrations in peripheral blood lymphocytes of exposed nuclear medicine personnel and control subjects, expressed as group mean values

Sub-group	Σ	Total number and distribution of structural CA					aberrant cells (%)
		B_1	B_2	Ac	Dic	Σ CA	
NS	40	1.38 ± 0.17	0.38 ± 0.10	0.68 ± 0.12	0.03 ±0.03	2.45 ± 0.21	1.19 ± 0.10
S	20	1.45 ± 0.22	0.25 ± 0.10	0.45 ± 0.11	0.05 ±0 .05	2.20 ± 0.21	1.08 ± 0.11
W	37	1.41 ± 0.17	0.30 ± 0.09	0.68 ± 0.12	0.03 ± 0.03	2.41 ± 0.21	1.16 ± 0.10
M	23	1.39 ± 0.22	0.39 ± 0.14	0.48 ± 0.12	0.04 ± 0.04	2.30 ± 0.24	1.13 ± 0.12
Ph	12	1.50 ± 0.31	0.17± 0.11	0.58 ± 0.19	-	2.25 ± 0.35	1.13 ± 0.18
Te	26	1.27 ± 0.20	0.38 ± 0.12	0.54 ± 0.13	0.08 ± 0.05	2.27 ± 0.26	1.08 ± 0.12
Nu	8	1.57 ± 0.30	0.43 ± 0.20	0.71 ± 0.29	-	2.71 ± 0.29	1.29 ± 0.10
En	7	1.50 ± 0.46	0.38 ± 0.26	0.63 ± 0.18	-	2.50 ± 0.53	1.25 ± 0.27
Cl	7	1.43 ± 0.37	0.29 ± 0.18	0.71 ± 0.36	-	2.43 ± 0.43	1.21 ± 0.21
EXPOSED		**1.40± 0.30↑**	**0.33 ± 0.07↑**	**0.60 ± 0.09↑**	**0.03± 0.02↑**	**2.37± 0.16↑**	**1.15 ± 0.08↑**
NS	40	0.45 ± 0.09	0.05 ± 0.03	0.18 ± 0.06	-	0.68 ± 0.10	0.36 ± 0.05
S	20	0.75 ± 0.16	0.10 ± 0.07	0.35 ± 0.11	-	1.20 ± 0.19*	0.55 ± 0.10
W	37	0.54 ± 0.09	0.08 ± 0.05	0.19 ± 0.07	-	0.81 ± 0.11	0.39 ± 0.06
M	23	0.57 ± 0.15	0.04 ± 0.04	0.30 ± 0.10	-	0.91 ± 0.18	0.48 ± 0.06
CONTROL		**0.55± 0.08**	**0.07± 0.03**	**0.23 ± 0.06**	**-**	**0.85 ± 0.09**	**0.43 ± 0.05**

NS-nonsmokers, S-smokers, W-women, M-men, Ph-physicians; Te-technologists, Nu-nurses, En-engineers, Cl-cleaners. ↑ significantly increased compared to control subjects; * significantly increased compared to nonsmokers; $p<0.01$ (multifactor ANOVA, post-hoc Scheffé test).

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ABSTRACT

Despite intensive research over the last few decades, there still remains considerable uncertainty as to the genetic impact of ionising radiation on human populations, particularly at low levels. The aim of this study was to provide data on genetic hazards associated with occupational exposure to low doses of ionising radiation in nuclear medicine departments. The assessment of DNA damage in peripheral blood lymphocytes of medical staff was performed using the chromosome aberration (CA) test. Exposed subjects showed significantly higher frequencies of CA than controls. There were significant inter-individual differences in DNA damage within the exposed population, indicating differences in genome sensitivity. Age and gender were not confounding factors, while smoking enhanced the levels of DNA damage only in control subjects. The present study suggests that chronic exposure to low doses of ionising radiation in nuclear medicine departments causes genotoxic damage. Therefore, to avoid potential genotoxic effects, the exposed medical personnel should minimise radiation exposure wherever possible. Our results also point to the significance of biological indicators providing information about the actual risk to the radiation exposed individuals.