Pathol. Oncol. Res. (2013) 19:323–328
DOI 10.1007/s12253-012-9587-8

RESEARCH

Melanoma Screening in a Hungarian Nuclear Power Plant

Veronika Tóth · Beáta Somlai · Zsófia Hatvani · József Szakonyi · István Gaudi · Sarolta Kárpáti

Received: 18 June 2012 / Accepted: 7 November 2012 / Published online: 15 December 2012

Abstract The industrial use of the ionizing radiation (IR) particularly stresses the safe work, regular health control is inevitable. Since previous occupational cohorts reported contradictory data on the incidence of melanoma among nuclear industry workers, and in few publications significant increase of it has been described, our clinic was requested by the industry to screen malignant skin tumours among the workers of a power plant. Within a year we have investigated 556 workers, 275 females and 281 males. Out of them 283, majorly males had been officially confirmed as to be employed at hazardous, but strictly controlled environment for an average of 18 years (1–32 years). To distinguish between IR and environmental UV (UVA+UVB) induced cutaneous malignancies we determined the sun and tanning bed exposure of the workers. One in situ melanoma developed in a woman with type I skin, bullous sunburns in the history, who had worked in safe environment for 26 years. Basal cell carcinoma was identified in two men, each of them worked for more than 20 years with IR (in hazardous environment). One had type I skin, the other had type II skin. These results didn't differ significantly (chi-squared test; $p=0$, 2437 and 1, 0) from the national population data and the results of Euromelanoma screening campaign in Hungary. Our data clearly show, that 1./UV exposure and skin type should be evaluated in occupation cohort studies. 2./The melanoma incidence was not significantly higher among the employees of the power plant than in the general Hungarian population, according to the results of our study, the only Hungarian power plant is safe as far as the skin carcinogenesis is concerned.

Keywords Sun exposure · Hazard of ionizing radiation · Nuclear power plant · Melanoma screening · Melanoma incidence

Abbreviations

ICRP	International Commission on Radiological Protection
IR	Ionizing radiation
MW	Megawatt
MPa	Megapascal
NTS	Nevada test site
NDR	National dose registry of Canada
VVER	Water–water energetic reactor
UV	Ultraviolet

V. Tóth (✉) · B. Somlai · Z. Hatvani · J. Szakonyi · S. Kárpáti
Department of Dermatology, Dermatooncology and Venerology,
Semmelweis University,
1085 Maria street 41,
Budapest, Hungary
e-mail: toveroka@yahoo.com

I. Gaudi
National Institute of Oncology,
1122 Ráth György street 7-9,
Budapest, Hungary

Introduction

Different external, often occupational causes may play a role in melanoma and non-melanoma skin cancer formation. The expected hazardous exposure in a nuclear plant is the ionizing radiation (IR). While industrial workers are not exposed to further "classic occupational" cutaneous carcinogens (e.g. tar products, arsenic), their private activities, similarly to that of the general population, more and more include regular exposure to environmental ultraviolet (UV) irradiation. While data of UV induced carcinogenesis might interfere with the IR occupational screening results, some previous studies missed to evaluate the UV exposure and the skin type among the screened nuclear power plant workers. Several studies were performed to clarify melanoma incidence and mortality among nuclear industry workers, however, the results were contradictory (Table 1). In a recent rewiew study no lower cancer risk was found for low-dose-rate and moderate-dose IR exposures (typical for occupational exposure) than for atomic bomb survivors [16].

The aim of the present work was: i./to screen workers in the only Hungarian nuclear power plant for melanoma and non-melanoma skin cancer, ii./to study possible causative relation between hazardous IR environment and melanoma formation. iii./to determine the UV exposure and skin type of the studied employees to exclude skin tumours of non IR origin.

Methods

Spot of the Study

Hungary's single nuclear power plant was established in 1976. The four Water–Water Energetic Reactor-440/213 type blocks were set in operation between 1982 and 1987. The VVER-440/213 delivered 440 MW electric power. Fuel rods contain low enriched uranium dioxide or equivalent. Reactor fuel rods are fully immersed in water kept at 15 MPa pressure so that it does not boil at normal (220 to over 300 °C) operating temperatures. Water in the reactor serves both as a coolant and a moderator. Intensity of the nuclear reaction is controlled by neutron absorbing control rods. The rods are inserted into the reactor from above, and depending on depth of insertion hinder the chain reaction. The reactor employs improved coolant pump and six primary coolant loops each with a horizontal steam generators, an emergency core cooling system, auxiliary feedwater systems and Accident Localization Systems. Due to the power augmentation, the nominal total power of the blocks increased from the original 440 MW electrical power to 500 MW in 2009. This electrical power covers almost the 40 % of the Hungarian electric production. The cumulative IR dosage of the workers is regularly controlled, they are regularly checked for general health and malignancies.

Screening Technique

The screening was conducted by trained dermatologists from the Semmelweis University. During the one year screening period 17 dermato-oncological examinations were organized at the plant, always with the contribution of two or three dermatologists. The screening was voluntary for all the 4,500 workers. The examined employees filled out a questionnaire (name, date of birth, number of the years they spent in the power plant). The type of the work was characterized as hazardous or non-hazardous one, dependent on

Table 1 Melanoma incidence and mortality among nuclear industry workers according to the recent studies

Author	Year	Screened population	Number of screened people	Increased risk of melanoma incidence (i)/ mortality(m)	Literature
Austin DF et al	1981	Lawrence Livermore National Laboratory's workers	5,100	yes (i)	[1]
Acquavella JF et al	1982	Los Alamos National Laboratory's workers	11,308	no	[2]
Acquavella JF et al	1983	Los Alamos National Laboratory's workers	20	no	[3]
Johnson CJ	1984	Mormon families (Nevada Test Site)	4,125	yes (i)	[4]
Smith PG	1986	Workers of the Sellafield plant of British Nuclear Fuels	14,327	no	[5]
Kendall GM et al	1992	National Registry for Radiation Workers	95,217	no	[6]
Carpenter L et al	1994	Workers of the United Kingdom Atomic Energy Authority, Atomic Weapons Establishment, Sellafield plant of British Nuclear Fuels	75,006	yes (m)	[7]
Austin DF et al	1997	Lawrence Livermore National Laboratory's workers	31	yes (i)	[8]
Moore DH et al	1997	Lawrence Livermore National Laboratory's workers	69	no	[9]
Sont WN et al	2001	Canadian Radiation Dose Registry nuclear industry workers	191,333	yes (i)	[10]
Whorton MD et al	2004	Lawrence Livermore National Laboratory's workers	17,785	yes (i)	[11]
Zielinski JM	2005	Radiation exposed dental workers	42,175	yes (i)	[12]
Telle-Lamberton M et al	2007	French Atomic Energy Commission's workers, General Company of Nuclear Fuel's workers	29,204	yes (m)	[13]
Cardis E et al	2007	Nuclear industry workers of 15 countries (15 country study)	407,391	no	[14]
Gun RT et al	2008	Australian participants in the British nuclear tests in Australia	10,983	yes (i)	[15]

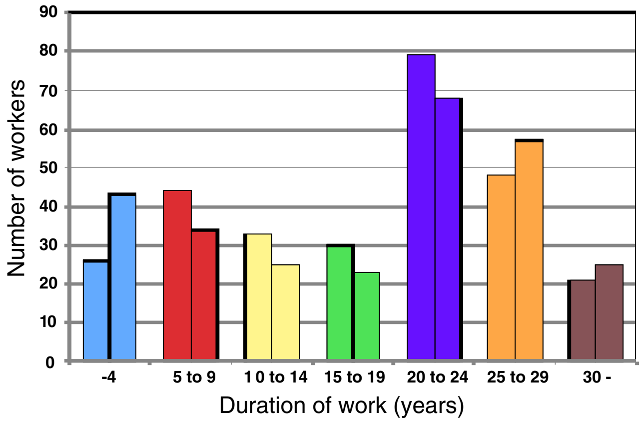


Fig. 1 Duration of work in the nuclear power plant (first columns: males, second columns: females)

the environment with/or without the possibility of IR exposure, without the cumulative data of IR dosage. In addition, everybody was asked for sun exposure habits (sunny hours/ day outdoor), number of bullous sunburns in the past, and frequency of possible tanning bed use. Skin tumours in the medical history were also registered. The skin type, cutaneous sings of UVA and UVB damage and the number of pigmented nevi were determined. Dysplastic nevi and tumour suspicious lesions were also analyzed by dermatoscopy. The lesions clinically suspicious for malignant tumours were removed and examined histologically.

Gender and Age of the Workers Involved in the Study

556 workers (12, 35 %) were examined. About half of them was male (n=281), and half female (n=275). The age range was between 20 and 60 years in both genders. From both gender most of the workers belonged to the age group 50–54 years.

Statistics

For statistical analysis a chi-squared test was used, $P<0.05$ was considered as statistically significant. Data were compared with the national population data and with the results of the Hungarian Euromelanoma screening campaign from the study year (2009). Yates's correction was applied because of the low case number.

Results

Evaluation of the Questionnaire Data

Duration of the work: Most of the screened population has been working in the power plant for 20–24 years (Fig. 1). We also examined in which extent the studied volunteers worked in more hazardous environment, and found, that mostly the males worked there in an average for 18 years. The work of females was mostly far from IR (Fig. 2), in a non-hazardous environment, where they had been working in an average for 19 years.

Exposure of workers to the sun and artificial UV radiation: From both gender most of the workers (102 males, 106 females) spent in an average two hours (h) outdoor daily. The females spent less time on the sun (0–1 h), while longer sun exposure (3–9 h, mostly agriculture work) was more typical for the males (Fig. 3). Most workers (107 males, 120 females) had never had bullous sunburn in their life. More males than females reported five or more severe sunburns (Fig. 4). These results are concordant with data of Fig. 3.

We also evaluated the history of the artificial UV exposure: 17 % of the females were frequent tanning bed users (41/234), while only 3 % of the males (8/273) reported that.

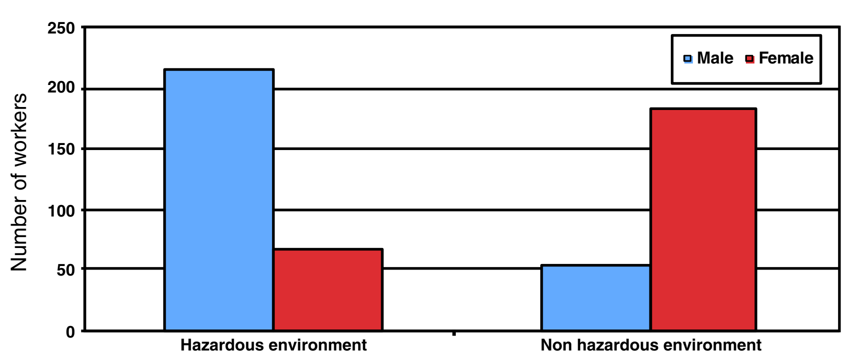
We studied the incidence of malignant skin tumours in the medical history. 1 % of the screened employees, 6 males and 1 female had previously malignant skin tumours, all of them were basal cell carcinomas.

Results of the Dermatological Screening

In both gender the most frequent skin was type II, about the same number of males and females belonged to this group (Fig. 5). The very light skin type I was detected in 48 females and in 17 males.

We also registered the cutaneous signs of chronic UV damage, and found actinic keratoses, solar lentigos and/or

Fig. 2 The hazard of ionizing radiation during work



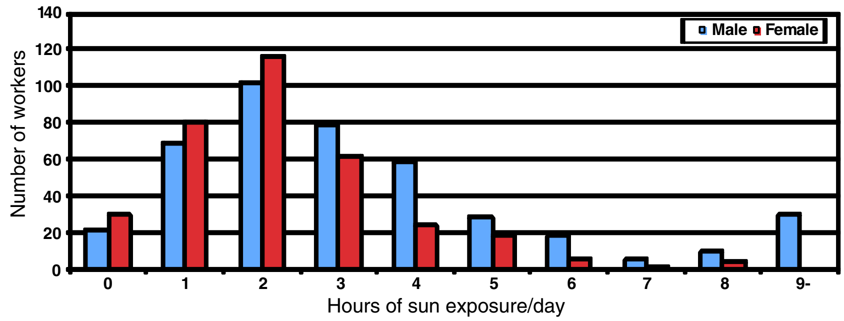


Fig. 3 Sun exposed hours/day

elastosis in 95 males and by almost half of the females (112/275) (Fig. 6).

Most of the workers had less than 10 melanocytic nevi (46 % of males, 61 % of females), and a very low percent of the screened population had more than 10 dysplastic nevi (2 % of males, 0, 4 % of females).

During the 1 year screening period we identified three histologically verified malignant skin tumours. An in situ malignant melanoma was detected in a 53-year-old female patient, who has been working for 26 years in the power plant in IR free environment. She had had four bullous sunburns, she was not a frequent tanning bed user and she had no any malignant skin tumour in the history. Her skin was type I with signs of chronic sun damage (solar lentigos, elastosis), and had less than ten nevi or dysplastic nevi. Basal cell carcinoma was verified in two male patients. Both of them have been working in hazardous environment at least for 20 years, none of them use frequently tanning bed, or had malignant skin tumour in the history. The younger male was 37 years old, had type I skin and had had 3 bullous sunburns, usually stays on the sun 3 h/day. The older male was a 53 year-old with type II skin and has never had bullous sunburn.

Discussion

The melanoma incidence has been continuously increasing worldwide within the last few decades [17, 18]. Several factors are indicated to induce melanoma, one of them could be IR, proven by animal studies. The early IR skin effects include transcription initiation of proinflammatory cytokine cascade (IL-1, -3, -5, -6, TNF-α), IL-8, epidermal growth factor receptor (EGF-R), adhesion receptors (ICAM-1, VCAM) in keratinocytes, endothelial cells and fibroblasts. The late reaction is marked by proliferation inhibition of epidermal stem cells, by overproduction of TGF-α1 leading to collagen overproduction of fibroblasts, and by lymphocytic fibrotic inflammation [19]. In athymic mice already very low doses of IR exposure to highly pigmented human melanoma xenografts induced melanoma metastases, while there were no metastases from non-irradiated tumor grafts [20]. Alpha irradiation of rodent skin does not produce ulceration or skin cancer, because the majority of the target cells in the dermis are deeper than the range of alpha particles [21]. IR might also contribute to basal and squamous cell carcinoma formation by stochastic effect [22, 23]. Since studies performed among nuclear industry workers delivered contradictory results (Table 1), we speculated to evaluate the UV irradiation as the most common non IR environmental factor among the workers. The aim of the present study was 1, to examine the melanoma and non-melanoma skin cancers 2, to evaluate the age, environmental UV exposure, tanning bed habits and skin type 3, to determine the duration of work in hazardous or non-hazardous working environment and the incidence of melanoma among the power plant workers.

The dermatological screening of 556 employees showed that the most frequent skin type was the type II in both genders and more females had lighter skin type (type I) than males. Moreover, UV skin damage (actinic keratoses, solar

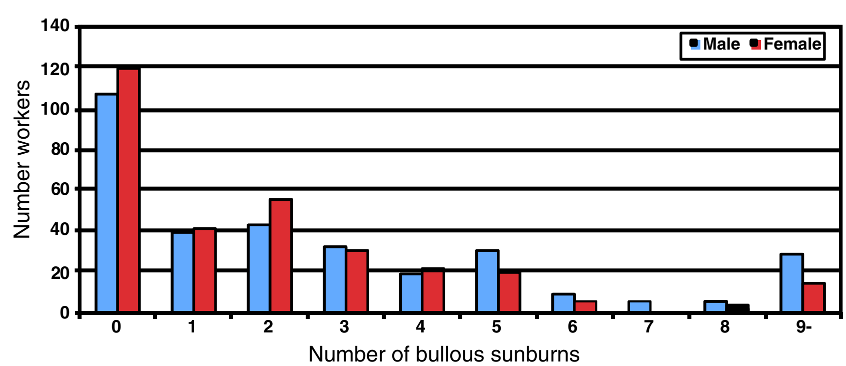
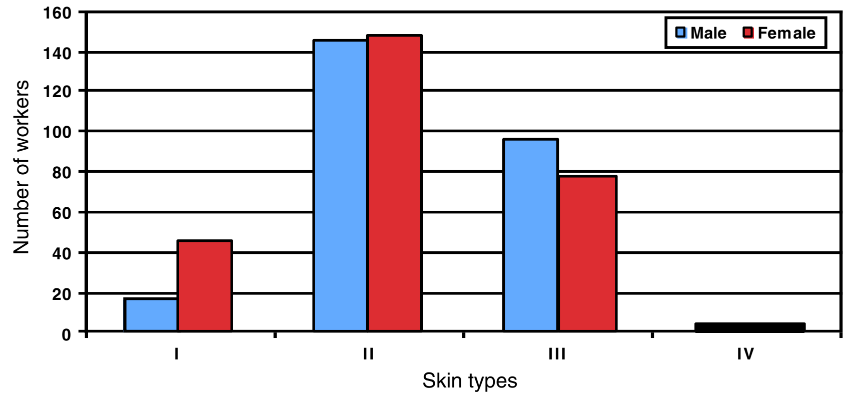


Fig. 4 Number of bullous sunburns

Fig. 5 Skin types



lentigos and elastosis) developed in higher incidence in females (almost 50 %) than in males (about 25 %). Female workers had spent less hours on the sun and had less sunburns in average than the males, but more females had light skin, and they use almost six times more frequently tanning bed than males, what may explain the higher incidence of UV skin damage among female employees.

During the 1 year screening period we identified three histologically verified malignant skin tumours. One in situ melanoma was diagnosed in a female patient, who has been working for 26 years in the power plant in ionizing radiation free environment. She had four bullous sunburns, skin type was I, and cutaneous signs of sun damage (solar lentigos, elastosis) also were observed.

In addition basal cell carcinoma was verified in two male patients. Both of them have been working with ionizing sources at least for 20 years, none of them use frequently tanning bed or had malignant skin tumour in the medical history. The younger male has type I skin and had 3 bullous

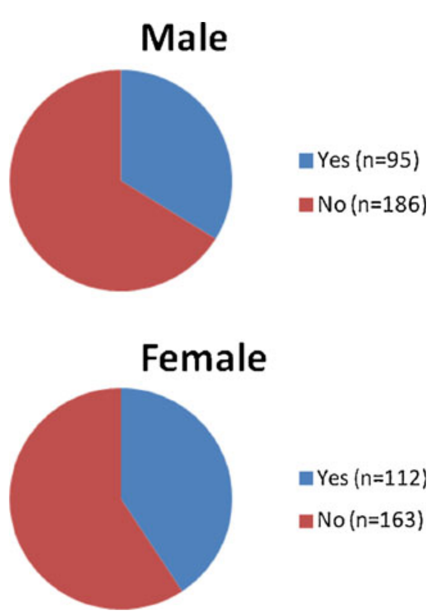


Fig. 6 Signs of sun damage on the skin

sunburns, usually stays on the sun 3 h/day. The other male has type II skin and has never had bullous sunburn.

The number of new melanoma cases has been growing year by year in Hungary as well. The melanoma incidence between 2003 and 2009 showed a continuous increase except in 2006 (2003: 100.000, 2009: 24/100.000). Between 2003 and 2009 female's new melanoma cases in each year exceeded that among males [24].

During the 1 year screening period we examined 12,35 % of the 4,500 employees (556 workers) and detected one in situ melanoma. Analyzing the data we should keep in mind that the screening was voluntary, so the participants of the screening were not randomly selected. Therefore our results were compared not only with the whole population's data, but also with the data of a voluntary melanoma screening campaign (Euromelanoma screening) in Hungary. In 2009 throughout the country the 6th Euromelanoma screening was hold. In the campaign 140 dermatologists examined 3,200 patients countrywide. The average age of the patients was 40,2 years, 74 % of them were females, 25 % were males. Four cases of malignant melanoma (one in situ melanoma, one Clark II melanoma, two Clark III melanomas), 10 cases of basal cell carcinoma and 1 case of morbus Bowen was histologically verified (unpublished data).

These data were compared with our screening results by chi-squared analysis. We didn't find significant difference between the power plant's screening data and the national melanoma incidence or the Euromelanoma screening's data (p=0, 2437 and 1, respectively).

In summary it might be concluded that the melanoma incidence was not significantly higher in the power plant than in the general Hungarian population. The causative factor of the only identified melanoma case, seems to be rather the UV radiation than the IR, since the patient worked in an IR free environment, reported four bullous sunburns, had skin type I and signs of cutaneous sun damage. Consequently, it may be raised that UV exposure, skin type and signs of UV damage should be evaluated in occupational cohort melanoma screening studies. Furthermore the melanoma incidence was not higher among the employees of the power plant than in the general Hungarian population, according to the results of our study, the only Hungarian power plant is safe as far as the skin carcinogenesis is concerned.

Acknowledgements We would like to express our thanks to H. Ócsai, Z. Battyáni, Á. Bégány, G. Liszkai, J. Oláh for the statistical data of the Euromelanoma campaign in Hungary and to F. Harmos, B. Hidvégi, P. Holló, Cs. Kaszab, D. Kuzmanovszki, V. Losonczi, A. Lukács, Á. I. Ottó, P. Silló, M. Szilágyi, A. Újfaludy, N. Wikonkál for the dermatological examination of the workers, and for the financial support to OTKA K73296 and TAMOP-4.2.1/B-09/1/KMR-2010-0001.

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