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Occupational exposure of medical radiation workers in Lithuania, 1991–2003

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Background. The aim of the study was to determine the status of occupational exposure among medical radiation workers in Lithuania, 1991–2003.

Material and methods. Medical radiation workers (N = 1331) and annual dose records (N = 13801) were studied during 1991–2003. Three study groups were established according to occupational categories (radiology, radiotherapy and nuclear medicine) and they were divided into subgroups by occupations. Monitored rate was evaluated. Average annual effective doses in three periods by occupational categories, gender, and distribution of dose ranges were calculated.

Results. Higher occupational exposure of diagnostic radiologists (1.94 mSv) and nuclear medicine technologists (2.12 mSv) was observed. The total average annual occupational dose of medical radiation workers in the three periods decreased from 1.92 to 1.17 mSv for radiology; from 1.90 to 1.13 mSv for radiotherapy and from 1.64 to 1.35 mSv for nuclear medicine workers. Men (2.19 mSv) received the highest exposure in radiology, while women (1.94 mSv) in nuclear medicine sectors. The distribution of annual dose records shows that 97.4% of the doses received were below 5 mSv; 2.0% exceeded 20 mSv (0.2% made up over 50 mSv in a single year).

Conclusions. Average annual effective doses decreased among all the occupational categories of medical radiation workers during 1991–2003. The impact of the levels of ionizing radiation doses determined for medical radiation workers in relation to cancer risk should be further examined.

Key words: medical radiation workers, average annual effective dose, dose ranges

INTRODUCTION

Evidence obtained from the experimental, epidemiological and other studies on human population shows that high doses of ionizing radiation (IR) induce cancer. Quantitative risk estimates are mainly derived from acute exposures to high doses, nuclear bomb survivors and radiotherapy patients in particular. Cancer risk estimates after the protracted exposure to low doses of IR are mostly based on extrapolation of the findings of the high dose studies (1–3).

Cancer induction is one of the main potential adverse long-term health effects in the low dose range. The risk associated with low doses of IR has gained a new interest. Some cohort studies of medical radiation workers determined a positive association between the occupational exposure to IR and all cancers (4–8), while some of them did not (9–10). However, cancer risk estimates in the low dose range still remain controversial, especially the shape of the dose-effect relationship (11).

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Analysis of the relationship between exposure (dose) and cancer risk (response) is very important, because it is essential for risk assessment. In the absence of individual dose estimates, many investigators have used proxy measures that reflect historical changes in radiation exposure among medical radiation workers (12). Dosimetry uncertainties bring additional difficulties in deriving risk estimates of low dose.

Lithuania is a country with one nuclear power plant (two reactors in Ignalina NPP). The dose estimates for some occupational groups (nuclear workers, flight crews, dentists and workers of general industry, research and medicine) in Lithuania were presented in literature (13–16).

The dose of IR of medical radiation workers in radiology, radiotherapy and nuclear medicine was not evaluated during 1991–2003. Cancer incidence, mortality of medical radiation workers, various confounding factors, such as smoking, drinking etc. are being studied at the Institute of Oncology, Vilnius University (17). Therefore, the occupational exposure (average annual effective dose, distribution by dose ranges etc.) of medical radiation workers of all the accessible periods must be known for futher cancer risk evaluation.

The aim of the study was to determine the status of occupational exposure of medical radiation workers in Lithuania, 1991–2003.

MATERIALS AND METHODS

Man-made irradiation of occupationally exposed persons is quantified and integrated into the system of dose limitation. The legal basis for radiation protection of radiation workers (18) was established according to the International Atomic Energy Agency (IAEA), International Commission on Radiological Protection (ICRP) as well as other international requirements and recommendations (19–21). The measurement of external exposure in Lithuania has been carried out since 1950, and sufficient experience has been accumulated in this field. A nationwide system of individual monitoring has been operating since 1991. Criteria for approval are based on the main requirements of ISO / IEC 17025 (22) Standard.

This paper will concentrate on whole-body doses received by medical radiation workers in all the occupational categories among all occupations. Persons having at least one annual dose summary record with an IR-related occupation were included in the analysis. The list of medical radiation workers was introduced to the Radiation Protection Centre (RPC) requesting to specify their annual doses received. Information about 1331 subjects was received. No information on occupational exposure was received concerning 43.1% of medical radiation workers: 141 men (6.0%) and 869 women (37.1%). These subjects were excluded from the analysis.

Medical radiation workers (N = 1331) were studied during 1991–2003. Distribution of medical radiation workers in three occupational categories (radiology, radiotherapy and nuclear medicine) by gender shows that women predominate over men around four times (Table 1).

Annual dose records (N = 13801) were analyzed. The monitored rate was calculated by proportion. Table 2 shows the monitored rate (%) for medical radiation workers in three occupational categories.

The cut-offs from the exposure distribution for men and women were determined in three periods: 1991–1995, 1996–2000 and 2001–2003. The exposure metric used in the analysis was the arithmetic mean of average dose mean values and standard deviation (SD). The three study groups by occupational categories (radiology, radiotherapy and nuclear medicine) were established and they were divided into subgroups by occupations (physicians: diagnostic radiologists, diagnostic and therapeutic radiologists and radiation therapists; technologists: radiology technologists, medical radiation technologists, nuclear medicine technologists; technicians; orderlies). Five exposure groups were taken: ≤4.99, 5.00–9.99, 10.00–14.99, 15.00–19.99 and ≥20 mSv. Extremity-high doses (≥50 mSv) were separated. Average annual effective doses, dose range distribution (%) were calculated. Doses were assigned to the year when the dosimeter was issued, even though some of the dosimeters may actually have been worn during part of the subsequent year. All the doses are reported in millisieverts (mSv).

Nuclear medicine and radiotherapy were performed only in the largest university hospitals, while radiology was performed mostly in all the regional hospitals of Lithuania. Each medical radiation worker received an individual dosimeter with a personal number. The dosimeter was worn on the most exposed place on the body, generally on the front left part of thorax, outside the shielding apron. The thermoluminescent dosimetry (TLD) systems: DTU (1991–1994) and RADOS (1995–2003) were used for measurements of doses to extremities and for external exposure measurements of medical radiation workers. Dose quantity limits were defined as in International Commission on Radiological Protection (ICRP) Publication 60: an occupational dose limit of an average of 0.02 Sv per year averaged over a 5-year period, with further provision that the dose should not exceed 0.05 Sv in any single year (2). The operational dose quantities used for external exposure were the personal dose equivalent Hp (10),

Table 1. **Numbers of monitored workers and distribution (%) by gender in all the occupational categories of medical radiation workers, Lithuania 1991–2003**

Occupational category	1991–1995		1996–2000		2001–2003	
	N	%	N	%	N	%
Men						
Radiology	108	10.81	140	12.01	104	15.29
Radiotherapy	22	2.20	21	1.80	18	2.65
Nuclear medicine	7	0.70	9	0.77	9	1.32
Total	137	13.71	170	14.58	131	19.26
Women						
Radiology	760	76.08	893	76.59	445	65.44
Radiotherapy	73	7.31	74	6.35	78	11.47
Nuclear medicine	29	2.90	29	2.49	26	3.82
Total	862	86.29	996	85.42	549	80.74

Table 2. **Numbers of monitored workers and monitored rate (%) in all the occupational categories of medical radiation workers, Lithuania 1991–2003**

Occupational category	Monitored workers (N)	Monitored rate (%)
Radiology	1147	61.5
Radiotherapy	136	34.8
Nuclear medicine	48	55.8
Total	1331	56.9

Table 3. **Average annual effective dose (AAED, mSv) for medical radiation workers (men and women, mSv) in Lithuania, 1991–2003**

Occupation	1991–1995		1996–2000		2001–2003		Total	
	AAED, mSv	SD	AAED, mSv	SD	AAED, mSv	SD	AAED, mSv	SD
Radiologists (diagnostic)	2.32	±1.5	1.90	±1.1	1.59	±0.9	1.94	±1.2
Radiology technologists	2.11	±1.3	1.43	±0.6	1.09	±0.3	1.54	±0.7
Orderly	1.65	±0.7	1.30	±0.5	1.00	±0.3	1.32	±0.5
Other (Technicians)	1.58	±0.9	1.29	±0.5	0.99	±0.3	1.29	±0.6
Total	1.92	±1.1	1.48	±0.7	1.17	±0.5	1.52	±0.8
Radiation therapists	1.78	±0.8	1.34	±0.5	0.93	±0,2	1.35	±0.5
Medical radiation technologists	2.22	±1.4	1.47	±0.6	1.11	±0.3	1.60	±0.8
Orderlies	2.10	±1.3	2.00	±1.0	1.31	±0.6	1.80	±1.0
Other (Technicians)	1.50	±0.7	1.24	±0.4	1.16	±0.3	1.30	±0.5
Total	1.90	±1.1	1.51	±0.6	1.13	±0.4	1.51	±0.7
Radiologists (diagnostic and therapeutic)	1.88	±1.2	1.05	±0.3	1.07	±0.2	1.33	±0.6
Nuclear medicine technologists	2.54	±2.0	1.79	±0.7	2.03	±0.9	2.12	±1.2
Orderly	1.46	±0.4	1.67	±0.8	0.95	±0.2	1.36	±0.5
Other (Technicians)	0.68	±0.1	1.25	±0.3	1.33	±0.4	1.09	±0.3
Total	1.64	±0.9	1.44	±0.5	1.35	±0.4	1.48	±0.6

Table 4. **Average annual effective dose (AAED, mSv) for medical radiation workers by gender, Lithuania 1991–2003**

Occupational category	1991–1995		1996–2000		2001–2003		Total	
	AAED, mSv	SD	AAED, mSv	SD	AAED, mSv	SD	AAED, mSv	SD
Men								
Radiology	2.42	±1.6	2.18	±1.4	1.98	±1.3	2.19	±1.4
Radiotherapy	1.90	±1.0	1.37	±0.5	1.01	±0.2	1.43	±0.6
Nuclear medicine	1.94	±1.2	1.13	±0.3	1.12	±0.2	1.40	±0.7
Total	2.09	±1.3	1.56	±0.7	1.37	±0.6	1.67	±0.9
Women								
Radiology	2.06	±1.2	1.44	±0,6	1.16	±0.4	1.55	±0.7
Radiotherapy	2.05	±1.2	1.53	±0.7	1.04	±0,2	1.54	±0.7
Nuclear medicine	2.31	±1.8	1.70	±0.7	1.81	±0.9	1.94	±1.1
Total	2.14	±1.4	1.56	±0.7	1.34	±0.5	1.68	±0.9

Table 5. **Distribution of annual dose records (Nr) for total medical radiation workers by dose ranges in Lithuania, 1991–2003**

Dose ranges, mSv	1991–1995		1996–2000		2001–2003	
	Nr	%	Nr	%	Nr	%
≤4.99	3199	94.5	5426	98.4	4964	99.2
5.00–9.99	116	3.4	61	1.1	34	0.7
10.00–14.99	42	1.2	15	0.3	3	0.1
15.00–19.99	11	0.3	3	0.1	1	0.04
≥20 (≥50*)	18 (2*)	0.5	7 (0*)	0.1	1 (1*)	0.04
Total	3386	100.00	5512	100.00	5003	100.00

* Extremity doses

where minimum registered dose level (MDL) was 0.01 mSv. Hp (10) values higher than MDL were recorded and reported as the effective dose. The background level was subtracted from all the dose records. To subtract, natural background average doses measured in the premises of Personal Dosimetry Subdivision were used.

RESULTS

The total average annual occupational dose for medical radiation workers in Lithuania during 1991–2003 decreased from 1.92 to 1.17 mSv for radiology workers; from 1.90 to 1.13 mSv for radiotherapy workers and from 1.64 to 1.35 mSv for nuclear medicine workers. Higher exposure was observed for diagnostic radiologists (1.94 mSv) and nuclear medicine technologists (2.12 mSv) (Table 3).

A detailed analysis of average annual effective doses received for medical radiation workers by gender was performed. During 1991–2003, the average annual effective dose decreased from 2.09 to 1.37 mSv for men and from 2.14 to 1.34 mSv for women, respectively. Men (2.19 mSv) received higher average annual effective doses in radiology, while women (1.94 mSv) did in nuclear medicine (Table 4).

All the doses received were included in the analysis. The distribution of annual personal dose records shows that 97.4% of the received dose records were below 5 mSv. The proportion increased from 94.5 to 99.2% during three periods (Table 5). On the contrary, doses over 5.0 mSv decreased from 5.4% (in 1991–

1995) through 1.6% (in 1996–2000) to 0.8 (in 2001–2003). 2.0% (N = 26) of the doses received were exceeding the occupational dose limit (of an average of 20 mSv per year averaged over 5-year period). 0.2% (N = 3) were extremity doses (over 50 mSv in a single year), but none received 100 mSv during a 5-year period, proposed by ICRP (6).

DISCUSSION

Average annual occupational dose values in Lithuania are similar to those of China medical radiation workers: the average annual effective dose in China during 1986–2000 has fallen from 2.22 to 1.50 mSv for diagnostic radiology; from 1.50 to 0.90 mSv for radiotherapy and from 1.60 to 1.20 mSv for nuclear medicine workers (23). On the other hand, the average annual occupational dose values are exclusive: IARC monographs on the evaluation of carcinogenic risk to humans 2000 (24) show the trends in worldwide occupational exposure to man-made sources of radiation for medical uses by periods 1975–1979, 1980–1984 and 1985–1989, and the annual average effective dose to monitored workers (mSv) were 0.78, 0.60 and 0.47, respectively. However, when X-radiation was first used, in the early twentieth century, radiologists were exposed to high doses of X-rays, but now these doses are usually low because of improved shielding and technology, and greater distance from the radiation source. The corresponding values of average annual effective doses obtained for Lithuania in this study are approximately twice the values cited by IARC and UNSCEAR documents. This can be explained by unique circumstances of each country. The values of average annual effective dose allow to evaluate quantitative occupational exposure in Lithuania and to demonstrate the need for action in this field. For example, production of X-ray equipment is not subject to any regulations, and necessary technical specifications and requirements are not implemented.

There were 3 medical radiation workers in Lithuania who received an occupational exposure exceeding the dose limit (50 mSv in a single year), but none received 100 mSv in a 5-year period, proposed by ICRP (6). However, there is a probability that the dose recorded does not reflect the actual exposure, but the fact that the individual dosimeter may sometimes be left in the areas where it could be irradiated.

The distribution of annual personal doses in Lithuania shows that 97.4% of dose records were below 5 mSv. Dose ranges over 5.0 mSv clearly decreased by periods: from 5.4% (in 1991–1995) through 1.6% (in 1996–2000) to 0.8% (in 2001–2003). This may be explained by the effect of the increased monitoring rate for medical radiation workers in our country. A. Koczynski et al. study shows similar results of occupational exposure in Poland (25): 97.0% controlled workers received doses below 5 mSv. There were 3 cases of extremity doses, but not for medical personnel (only in industrial radiography units). Distribution of annual doses by dose intervals in Portugal (1986–1988) shows that 97.8% of the controlled workers received doses below 5 mSv; and extremity doses were not registered among medical radiation workers (26).

CONCLUSIONS

The total average annual effective doses decreased among all the occupational categories of medical radiation workers during 1991–2003: from 1.92 to 1.17 mSv for radiology, from 1.90 to 1.13 mSv for radiotherapy, and from 1.64 to 1.35 mSv for nuclear medicine workers while among gender: from 2.09 to 1.37 mSv for men and from 2.14 to 1.34 mSv for women.

The values of average annual effective doses obtained for Lithuania in this study are approximately twice the values cited by IARC and UNSCEAR documents, but are similar to those of medical radiation workers in China.

The values of average annual effective dose allow to evaluate quantitative occupational exposure in Lithuania and to demonstrate the need for action in this field.

The results of this study are similar to those in other international studies (Poland, Portugal) because the distribution of annual dose ranges below 5 mSv shows that the controlled medical radiation workers received doses as worldwide, but they also differ from other studies because 3 workers in Lithuania received extremity doses.

The impact of these levels of ionizing radiation doses determined for medical radiation workers in relation to cancer risk should be further examined.

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MEDICINOS DARBUOTOJŲ, DIRBANČIŲ JONIZUOJANČIOS SPINDULIUOTĖS APLINKOJE, PROFESINĖ APŠVITA LIETUVOJE 1991–2003 M.

Santrauka

Darbo tikslas. Nustatyti Lietuvos medicinos darbuotojų profesinės apšvitos būklę 1991–2003 metais.

Medžiaga ir metodai. Buvo ištirti jonizuojančios spinduliuotės aplinkoje dirbantys medicinos darbuotojai (n = 1331) bei metinių dozių matavimai (n = 13801) 1991–2003 metais. Pagal profesines kategorijas (diagnostinė radiologija, spindulinė terapija ir branduolinė medicina) sudarytos trys tiriamosios grupės ir padalytos į pogrupius pagal specialybes. Buvo įvertintas dozimetrinės kontrolės rodiklis ir apskaičiuoti metinių efektinių dozių vidurkiai pagal profesines kategorijas bei darbuotojų lytį, taip pat dozių intervalų lygmenų pasiskirstymas.

Rezultatai. Didžiausia apšvita nustatyta diagnostinės radiologijos gydytojams (1,94 mSv) ir branduolinės medicinos asistentams (2,12 mSv). Vidutinės metinės efektinės dozės per 1991–2003 m. sumažėjo nuo 1,92 iki 1,17 mSv radiologijos, nuo 1,90 iki 1,13 mSv spindulinės terapijos ir nuo 1,64 iki 1,35 mSv branduolinės medicinos darbuotojams. Didžiausią apšvitą (2,19 mSv) vyrai gavo radiologijos, moterys (1,94 mSv) – branduolinės medicinos padaliniuose. Metinių dozių intervalų pasiskirstymas rodo, kad 97,4% gautų dozių buvo mažesnes už 5 mSv; 2,0% viršijo 20 mSv (0,2% viršijo 50 mSv/m).

Išvados. Vidutinės metinės apšvitos efektinės dozės 1991–2003 m. sumažėjo tarp visų profesinių medicinos darbuotojų kategorijų. Nustatytų jonizuojančios spinduliuotės dozių intervalų lygmenų įtaka vėžio rizikai turėtų būti tiriama toliau.

Raktažodžiai: medicinos darbuotojai, vidutinė metinė efektinė dozė, dozių intervalai