The risk of cancer among Lithuanian medical radiation workers in 1978–2004

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Key words: *cancer incidence; medical workers; ionizing radiation.*

Summary. *Objectives. To describe the cohort of Lithuanian medical radiation workers and to estimate the risk of cancer during 1978–2004.*

Methods. Analysis of cancer risk evaluation was done using the retrospective cohort method, an indirect standardization. The observed numbers of cancer cases were obtained from the National Cancer Registry. The expected numbers were based on the age- and gender-specific incidence rates for the general Lithuanian population in 5-year periods. The standardized incidence ratios and 95% confidence intervals (assuming that the incidence of cancer follows the Poisson distribution) were calculated.

Results. During the follow-up of 1978–2004, 159 cases of cancer were observed. There was no increased overall cancer risk in men (SIR=0.92, 95% CI=0.62–1.33, based on 29 cases) and women (SIR=0.97, 95% CI=0.81–1.15, based on 130 cases). The risk of leukemia among men and women was insignificantly increased.

Conclusions. During the follow-up period, the overall cancer risk among medical radiation workers was the same as in the general population of Lithuania.

Introduction

Humans are affected by various sources of ionizing radiation. The atomic bomb data are mostly based on a single acute radiation exposure, while there is a relative paucity of comparable epidemiologic data on cancer risk from chronic or fractionated exposures to low-to-moderate radiation doses, which are more common in the workplace. Nuclear power industry workers are generally exposed to lower radiation doses than were early medical radiation workers. The lack of statistical power does not enable detection of a low cancer risk associated with exposure to very low doses, yet excess risks for leukemia and multiple myeloma have been noted in some nuclear populations (1). The largest study of nuclear industry workers suggests that there may be a small increase in cancer risk even at the low doses and dose rates typically received by nuclear workers (2).

It is estimated that worldwide there are 2.3 million medical radiation workers, i.e. half of the total work force exposed to human-made sources of radiation (3). Medical radiation workers typically are exposed to low doses at low dose rates to various parts of the body, which allows assessment of cancer risks for many organs and tissues. Radiologists have been studied longer than any other defined population to assess the late effects of exposure to ionizing radiation as an occupational agent. The most consistent finding was increased mortality due to leukemia among early medical radiation workers employed before 1950, when the levels of radiation exposures were high. This, together with an increasing risk of leukemia with an increasing duration of work in the early years, provided evidence of an excess risk of leukemia associated with occupational radiation exposure in that period (4, 5), while findings on several types of solid cancers were less consistent (6–9). Our knowledge on which cancers are most likely to be induced by radiation comes from a much broader database than just the studies of medical radiation workers. The results of all studies were not homologous among countries. To date, there is no clear evidence of an increased cancer risk in medical radiation workers exposed to current levels of radiation doses. However, given a relatively short period of time for which the most recent workers have been followed-up and in view of the increasing usage of radiation in modern medical practices, it is important to continue to monitor the health status of medical radiation workers.

There were no data on the risk of occupational exposure in the former Soviet Union. These intriguing findings create a need for more cohort studies, espe-

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cially among medical radiation workers in the countries of the former Soviet Union. The aim of the present study was to describe the cohort of medical radiation workers in Lithuania and to estimate the risk of cancer during 1978–2004.

Materials and methods

Cohort definition and follow-up. This study was approved by the Bioethics Committee of Lithuania (Protocol No. January 27, 2002). The data were obtained from 107 medical institutions of Lithuania. The study cohort consisted of 2787 medical workers exposed to sources of ionizing radiation during 1948–2004. The following information on all workers was gathered: name, surname, date of birth, personal code, place of residence, affiliation, dates of employment and retirement.

The study was confined to workers who were alive at the beginning of the follow-up on January 1, 1978. A total of 387 (14%) persons were excluded because the duration of their employment was less than one year. Another 150 (5%) persons emigrated, died, or had been lost to the follow-up before 1978. The remaining 2250 persons (301 men and 1949 women), representing 81% of the target population, were included in the cancer incidence analysis.

Some characteristics of the cohort of medical radiation workers in Lithuania are shown in Table 1.

Medical radiation workers dealt with one of three occupational categories: diagnostic radiology (1777 persons, 243 men and 1534 women), radiotherapy (386 persons, 43 men and 343 women), and nuclear medicine (87 persons, 15 men and 72 women).

The beginning of the follow-up period was January 1, 1978, and the end was December 31, 2004. The beginning of the follow-up was 1978 because of the possibility of a reliable identification of all cancer cases in the Cancer Registry at the Institute of Oncology, Vilnius University. The follow-up period started one year after the date of the beginning of employment in the environment of ionizing radiation for those with the first entry after January 1, 1977. Workers who emigrated or died were followed up until the time of these events, while other medical radiation workers were followed up to December 31, 2004. For medical radiation workers who were lost to the follow-up after 1978, person-years were calculated to the date of discharge.

Vital status at the end of the follow-up. Vital status was ascertained for a total cohort of 2250 medical radiation workers (301 men and 1949 women) at the end of the follow-up (December 31, 2004). Information on vital status, dates of emigration and death was

Table 1. **Characteristics of medical radiation workers in Lithuania, 1950–2004**

Characteristic	Men (N=301)	Women (N=1949)	Total (N=2250)
Year of birth			
≤1930	62	246	308
1931–1959	171	1284	1455
1960–1980	68	419	487
Total	301	1949	2250
Beginning of employment			
1950–1959*	19	96	115
1960–1969	41	194	235
1970–1979	70	489	559
1980–1989	87	596	683
1990–1999	83	531	614
2000–2004	1	43	44
Total	301	1949	2250
Age at the beginning of employment, years			
20–24	44	418	462
25–29	95	371	466
30–34	50	308	358
35–39	34	256	290
40+	78	596	674
Total	301	1949	2250

*Nineteen medical radiation workers (4 men, 15 women) were included at the beginning of employment in 1948–1949.

obtained from the following main sources: Lithuanian Archives Department under the Government of the Republic of Lithuania; the Residents' Register Service and Migration Department under the Ministry of Interior.

The vital status of the medical radiation workers is presented in Table 2.

Identification of cancer cases. The registration of cancer incidence is based on compulsory reporting of all new cancer cases from all hospitals in Lithuania. The systematic information is available in a computerized database of the Cancer Registry since 1978. Data on cancer incidence in Lithuania for 1988–1992 and 1993–1997 periods correspond to the international standards and are published in IARC Scientific Publication No. 155 (10).

New cancer cases in the cohort of medical radiation workers were identified in the Cancer Registry through record linkage procedures by person's code, name, surname, father's name, place of residence, gender, and date of birth.

The cancer diagnoses were coded according to the WHO International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD–10) (11).

Occupational exposure. The data on occupational exposure in the former USSR were summarized in manuals. The information on doses for nuclear and medical radiation workers was precisely collected in the former USSR, but the access to any data related to individual doses was restricted.

In 1990, Lithuania regained independence. Now the situation has changed. Computerized data provide the possibility for various advanced studies, which require the tracing of individual people through the longer follow-up period. Lithuania has created its own radiation protection legislation. The nationwide system of personal monitoring has been operating since 1991. Systematic collection of radiation-related data on medical radiation workers in Lithuania was started in 1991 (12–16). Further information on the average annual effective dose of Lithuanian medical radiation workers in 1950–2004 was published in the study by Samerdokienė et al. (17). Study by Stadnych et al. in the former USSR (18) reported similar annual average effective doses (Table 3).

Statistical methods. Analysis of cancer risk evaluation was done using the retrospective cohort method. To calculate the expected cancer numbers, an indirect standardization method was used (19). The person-years at risk for each person were calculated from January 1, 1978, until December 31, 2004, or from one year after the date of the beginning of employment (from January 1, 1977, to December 31, 2004) until the date of death, emigration, or loss to the follow-up. The standardized incidence ratio (SIR) was

Table 2. **Total cohort of medical radiation workers and vital status at the end of the follow-up**

Vital status	Diagnostic radiology		Radiotherapy		Nuclear medicine		Total		Total
	men	women	men	women	men	women	men	women	
Total	243	1534	43	343	15	72	301	1949	2250
Alive	195	1403	35	292	14	68	244	1763	2007
Dead	38	98	6	41	1	3	45	142	187
Emigrated	3	21	1	3	0	1	4	25	29
Unknown	7	12	1	7	0	0	8	19	27

Table 3. **Annual average effective dose for medical radiation workers in Lithuania**

Period	Annual average effective dose, mSv			Data source
	diagnostic radiology	radiotherapy	nuclear medicine	
1950–1959	40	NA	NA	Sirotka, 1972, 1973
1960–1969	15	8.5	NA	Sirotka, 1972
1970–1990	2.2	3.6	3.5	Unpublished Atkocius data
1991–2003	1.6	1.6	1.7	RPC data
1980–1995*	1.0–4.1	NA	1.3–2.5	Stadnych et al., 1996

* Former USSR.

calculated as the ratio of observed to expected site-specific cancer cases. The observed numbers of cancer were obtained from the National Cancer Registry. The expected numbers of cancer cases were based on sex-specific incidence rates in five-year-age groups and in five-year periods in Lithuania. The cohort contributed 42 479 person-years of follow-up (5518 for men, 36 761 for women). The 95% confidence intervals (95% CI) were estimated assuming that the observed number of cancer cases follows the Poisson distribution (20–21). The *P* value of <0.05 was considered statistically significant.

Results

During the follow-up period, 159 cancer cases (29 among men and 130 among women) were identified; out of them, 13 cases of leukemia (3 among men and 10 among women) (Table 4).

Table 4 shows standardized incidence rates for cancer incidence in the study population. During the follow-up period, cancer incidence was not increased among medical radiation workers of both genders: SIR=0.92, 95% CI=0.62–1.33 and SIR=0.97, 95% CI=0.81–1.15 for men and women, respectively.

The risk of lung cancer among men (6 cases, SIR=0.81, 95% CI=0.30–1.77) was not increased. The risk of leukemia among men was insignificantly increased as compared with the expected numbers (SIR=3.30, 95% CI=0.68–9.63, based on 3 cases).

Among women, the risk of leukemia was insignificantly increased (SIR=2.67, 95% CI=0.92–4.20, based on 10 cases). The risk of breast cancer among women (25 cases, SIR=0.90, 95% CI=0.58–1.33) was not increased. An insignificantly increased risk was found for cancers of rectum (8 cases, SIR=1.48, 95% CI=0.64–2.91), uterus (13 cases, SIR=1.23, 95% CI=0.66–2.11), and thyroid (5 cases, SIR=1.63, 95% CI=0.53–3.80).

Table 4. **Observed (Obs) numbers of new cancer cases and standardized incidence ratios (SIRs) among medical radiation workers during the follow-up period of 1978–2004**

Cancer sites	ICD-10 codes	Men			Women		
		Obs	SIR	95% CI*	Obs	SIR	95% CI*
Lip, mouth, and pharynx	C01–14	0	–	–	2	1.89	0.23–6.82
Esophagus	C15	1	1.56	0.04–8.71	1	2.63	0.07–14.07
Stomach	C16	2	0.57	0.07–2.08	8	0.90	0.40–1.77
Colon	C18	0	–	–	5	0.81	0.30–1.89
Rectum	C19–21	1	0.65	0.02–3.64	8	1.48	0.64–2.91
Liver	C22	1	2.70	0.07–15.10	1	1.01	0.03–5.63
Gallbladder	C23–24	1	6.67	0.17–37.10	1	0.71	0.02–3.98
Pancreas	C25	1	0.85	0.02–4.72	2	0.61	0.07–2.20
Larynx	C32	0	–	–	1	3.85	0.10–21.40
Lung	C33-34	6	0.81	0.30–1.77	3	0.68	0.14–2.00
Bone and connective tissue	C40–41, 45–47, 49	0	–	–	1	1.12	0.03–6.26
Melanoma	C43	1	3.57	0.09–19.90	2	0.77	0.09–2.79
Skin	C44	3	1.19	0.25–3.47	15	0.90	0.50–1.48
Breast	C50	–	–	–	25	0.90	0.58–1.33
Cervix uteri	C53	–	–	–	8	0.70	0.30–1.38
Uterus	C54–55	–	–	–	13	1.23	0.66–2.11
Ovary	C56	–	–	–	9	0.91	0.42–1.73
Prostate	C61	7	2.10	0.85–4.33	–	–	–
Bladder	C67	1	0.68	0.02–3.76	1	0.68	0.02–3.82
Kidney	C64–66, 68	0	–	–	4	0.93	0.25–2.37
Brain	C70–72	1	1.96	0.05–10.90	2	0.83	0.10–3.00
Thyroid	C73	0	–	–	5	1.63	0.53–3.80
Non-Hodgkin's lymphoma	C82–85, 88, 90	0	–	–	3	1.31	0.27–3.83
Leukemia	C91–96	3	3.30	0.68–9.63	10	2.67	0.92–4.20
All sites	C00-96	29	0.92	0.62–1.33	130	0.97	0.81–1.15

*95% confidence intervals.

Discussion

The cohort of medical radiation workers did not reveal any work-related excess risk of cancer from ionizing radiation. The SIRs of Lithuanian medical radiation workers were similar to the rates in the U.S. (6, 22) and Canada (23) cohorts (Table 5).

The long latent period between radiation exposure and cancer development together with the multistage nature of tumorigenesis makes it difficult to distinguish radiation-induced changes from those alterations that occur once the process has been initiated. Radiation-induced cancers do not appear to be unique or specifically identifiable (1). In our study, the risk of leukemia (excluding chronic lymphocytic leukemia, which has not been associated with radiation exposure) was insignificantly increased among men (3 cases, SIR=3.30, 95% CI=0.68–9.63) and women (10 cases, SIR=2.67, 95% CI=0.92–4.20). In most studies, the SIRs for leukemia were increased in the earliest subcohorts, whether defined by year of registration, certification, or birth. The data from four cohorts provided an evidence of excess leukemia risk among early medical radiation workers who were employed before 1950 (22).

The risk of lung cancer among men (6 cases, SIR=0.81, 95% CI=0.30–1.77) and the risk of breast cancer among women (25 cases, SIR=0.90, 95% CI=0.58–1.33) were not increased. The low SIRs for lung cancer might be explained by the relative young study population, while lung cancer of radiogenic origin appears only at older ages and is most common among men. Only 115 (5.1%) workers were aged 55 years and more. The risk of breast cancer was not increased either.

Firstly, the cohort of medical radiation workers was relatively small (N=2250) and contributed 42 479 person-years. Secondly, the cohort of medical radiation workers in Lithuania was relatively young (the mean age at the first exposure was 37 years and at the end of the follow-up was 56 years). These facts explain the small number of cancer cases. It was impossible to make conclusions for various sites of cancer because of the small numbers of cancer cases, especially among men (N=301), where the analysis was limited. The majority (86%) of Lithuanian medical radiation workers in the study cohort were women. Half of all medical radiation worker cohorts worldwide were composed only of men, while other cohorts were mixed: in the United States of America, 42%; in Canada, 26%; in China, 17%; and in Denmark, 45% of women.

The relatively small numbers of cancer cases do not allow making final conclusions about elevated cancer risk among medical radiation workers.

Conclusions

During the follow-up period, overall cancer risk among medical radiation workers was the same as in the general population of Lithuania.

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Table 5. **SIRs for overall cancers and leukemia in cohorts of medical radiation workers**

Cohort and sex	All cancers (cases)	Leukemia (cases)
USA (diagnostic radiology)		
Men	0.94 (884)	1.04 (27)
Women	1.07 (2408)	1.12 (48)
China (x-ray workers)		
Men	1.24 (679)	2.29 (36)
Women	1.02 (157)	1.74 (8)
Denmark (radiation therapy)		
Men and women	1.07 (163)	0.70 (2)
Canada (radiation workers)		
Men	0.64 (561)	0.57 (16)
Women	0.86 (869)	0.44 (10)
Lithuania (medical radiation workers)		
Men	0.92 (29)	3.30 (3)
Women	0.97 (130)	2.67 (10)

Adapted from Yoshinaga, 2004 (22).

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Lietuvos medicinos darbuotojų, dirbusių jonizuojančiosios spinduliuotės aplinkoje, rizika susirgti piktybiniais navikais 1978–2004 m.

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Raktažodžiai: sergamumas piktybiniais navikais, medicinos darbuotojai, jonizuojančioji spinduliuotė.

Santrauka. *Tikslas.* Aprašyti Lietuvos medicinos darbuotojų, dirbusių jonizuojančiosios spinduliuotės aplinkoje, kohortą ir įvertinti riziką susirgti piktybiniais navikais 1978–2004 m. laikotarpiu.

Metodai. Medicinos darbuotojų, dirbusių jonizuojančiosios spinduliuotės aplinkoje, rizika susirgti piktybiniais navikais tirta retrospektyviuoju kohortiniu metodu, naudojant netiesioginės standartizacijos būdą. Apskaičiuoti standartizuoti sergamumo santykiai. Tikėtini piktybinių navikų atvejai apskaičiuoti taikant Lietuvos populiacijos sergamumo piktybiniais navikais rodiklius pagal amžių ir lytį. 95 proc. pasikliautinieji intervalai apskaičiuoti, darant prielaidą, jog piktybiniai navikai pasiskirsto pagal Puasono modelį.

Rezultatai. Medicinos darbuotojų, dirbusių jonizuojančiosios spinduliuotės aplinkoje, rizika susirgti piktybiniais navikais, palyginti su visos Lietuvos gyventojų rizika tuo pačiu laikotarpiu, nebuvo padidėjusi nei tarp vyrų (29 atvejai, SSS=0,92, 95 proc. PI=0,62–1,33), nei tarp moterų (130 atvejų, SSS=0,97, 95 proc. PI=0,81–1,15). Nustatyti padidėję, tačiau statistiškai nereikšmingai, standartizuoti sergamumo santykiai leukozių atžvilgiu.

Išvados. Stebėjimo laikotarpiu medicinos darbuotojų, dirbusių jonizuojančiosios spinduliuotės aplinkoje, rizika susirgti piktybiniais navikais nesiskyrė nuo bendrosios Lietuvos populiacijos rizikos susirgti piktybiniais navikais.

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