Radiation Protection Dosimetry (2008), Vol. 130, No. 2, pp. 239–243
Advance Access publication 28 March 2008
doi:10.1093/rpd/ncm490

SCIENTIFIC NOTE

OCCUPATIONAL EXPOSURE OF MEDICAL RADIATION WORKERS IN LITHUANIA, 1950–2003

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Received July 19 2007, revised October 17 2007, accepted November 19 2007

This study presents the summary of historical exposures, measurement practice and evolution of the recording of the individual doses of medical radiation workers during 1950–2003 in Lithuania. The aim of this study is to present occupational exposure of medical radiation workers in Lithuania since the earliest appearance period. Data from publications have been used for the earliest two periods prior to 1969; data from the archives of the largest hospitals, for the period 1970–1990 and data from Lithuanian Subdivision of Individual Dosimetry of Radiation Protection Center, for the period 1991–2003. The analysis of the data obtained from personal records allows to conclude that the average annual effective dose of Lithuanian medical radiation workers was greatly reduced in radiology, radiotherapy and nuclear medicine in all occupational categories from 1950 to 2003. During the last period 1991–2003 extremity doses clearly decreased and after 1994 were no longer present in Lithuania.

INTRODUCTION

There are quite a few known facts about practice of the measurement, validation of the radiation exposure of the medical radiation workers in Lithuania while it was incorporated in the USSR from 1950 to 1990. The main sources on radiation measurement practice and data on occupational exposures in the former USSR were summarised in manuals and the literature on radiation safety, measuring instruments and methods of measurements that were available since 1959[1–6]. The information on occupational exposure was limited to the broad occupational categories; no case–control or cohort data on radiologists were available. The information of doses for nuclear and medical radiation workers was being collected very precisely in the former USSR, but the access to data pertaining to individual doses was restricted. Nuclear workers were predominantly exposed to low occupational doses over a long period and, in general, reliable individual dosimetric data are usually available[7,8]. The systematic radiation-related studies for medical radiation workers in Lithuania are being performed since 1991[9–12].

The first information on medical radiation workers in Lithuania was obtained in 1972[13,14]. Studies of similar nature began in other countries of the former USSR[15,16] and worldwide almost at the same time, but only the cohorts in Japan, China and Canada had sufficient power to supply the featured dose information[17]. There is a lack of studies about overall individual dosimetry among medical radiation workers.

The authors present a summary of the historical exposures and measurement practice and the evolution of recording of individual doses to medical radiation workers during 1950–2003 in Lithuania. The aim of this study is to present occupational exposure (the average annual effective dose) of medical radiation workers in Lithuania since the earliest appearance period.

MATERIALS AND METHODS

Medical radiation workers consist of three occupational categories, according to job classification: radiology, radiotherapy and nuclear medicine. The occupational exposure data for the radiology group were being traced in all available archives since 1950; for radiotherapy, since 1960 and for nuclear medicine, since 1970. These periods correspond to the start of extensive application of radiology, radiotherapy and nuclear medicine in Lithuania. Because the availability and quality of badge dose record data differs as per the period, the data were grouped into periods: prior to 1959, 1960–1969, 1970–1990, 1991–2003. For the earliest two periods prior to 1969 we have used data from publications[13,14]; for the period 1970–1990, data from the archives of the largest hospitals; for the period 1991—2003, data from the Lithuanian Subdivision of Individual Dosimetry of Radiation Protection Center (RPC).

The average annual effective dose of medical radiation workers was estimated by correlating to the types of dosemeter in all periods and practices applied and compared with the doses of the medical radiation workers in other countries. Three methods of individual dosimetry were the most common in

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Table 1. Badge dose estimation methods by periods.

Countries	Periods			
	1950–1959	1960–1969	1970–1990	1991–2003
Lithuania	Ionisation chambers, Film	Ionisation chambers, Film	Ionisation chambers, Film	TLD
USA	Film	Film, TLD	Film, TLD	
Italy	Film	Film, TLD		
Finland		Film, TLD		TLD
Austria		Film, TLD		
France			Film, TLD	
Portugal			Film	
Poland, Greece				Film, TLD
Turkey, Korean				Film, TLD
Norway, Netherlands				TLD

the former USSR (including Lithuania): ionisation chambers (KID-2; DK-02; DKP-50; DKS-04); film dosimetry (IFK-2.3; IFK-2.3M; IFKU; AGFA) and TLD (LiF; IKS-A). Methods used during different periods worldwide[18–21] and in Lithuania are shown in Table 1.

The devices used in the former USSR, prior to 1970, were the Roentgen meters (DKZ-2M, MRM-1, MRM-2, PMR-1, 'CACTUS') and the radiometers ('SVET-3, 'KRISTALL', SG-42 for gamma rays; 'LUC-A', 'SEVAN'/DP-11-B, 'TISS' for beta and gamma rays; SC-3, RPN-1 for neutrons and RUP-1, RUS-5 for all sorts of radiation). The devices used after 1970 were the condenser-type dosemeters (KID-1, DK-0,2, KID-2 for individual dosimetry of X- and gamma rays), film dosimetry (multipole types IFK-2,3; AGFA-3) and thermoluminescence crystal (ILK-3 for soft X-ray and beta flows; multipole types with Cd filters for neutron flow in individual dosimetry)[12,17,18]. The dosemeters used in Lithuania were PMR-1, 'CACTUS',

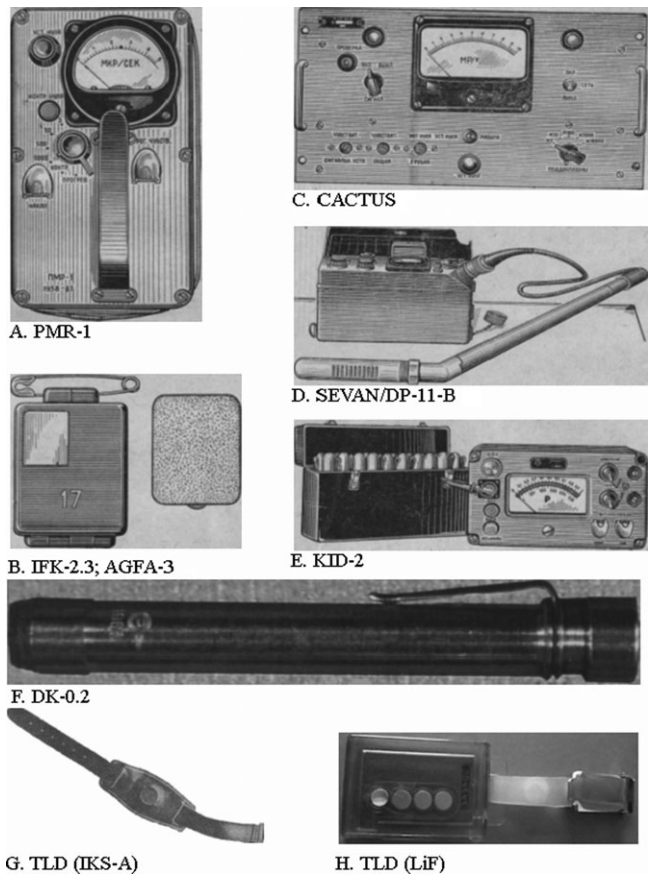

Figure 1. Types of dosemeters.

Table 2. The technical records of the commonly used dosemeters in the former USSR, Lithuania 1950–2003.

Type of dosemeter	Measuring ranges	Resolution, %	Period in use
PMR-1	0–5000 μR/s	±30	1950–1959
ID-1	20–500 rad	±20	1960–1969
ID-11	10–1500 rad	±15	1960–1969
DP-70MP	50–800 rad	±25	1960–1969
DP-22V	2–50 R	±10	1970–1990
DK-0.2	10–200 mR	±15	1970–1990
KID-2	0.005–1 R	±15	1970–1990
Film (IFK-2.3)	0.2–4 mSv	±10	1970–1990
Film (AGFA)	0.5–2 mSv	±25	1970–1990
TLD (IKS-A)	0.05–1000 rad	±20	1970–1990
TLD (LiF)	0.01–100 mSv	±15	1991–2003

Adopted from the cited Russian sources.

Table 3. The monitored medical radiation workers in Lithuania, 1950–2003.

Occupational categories	1950–1959	1960–1969	1970–1990	1991–2003
Radiology	865	1018	1200	1737
Radiotherapy	NA	78	112	382
Nuclear medicine	NA	NA	62	84

'SEVAN', KID-2, film (IFK-2,3, AGFA-3) and TLD (IKS-A, LiF) (Figure 1).

The measuring ranges, resolutions and frequency of monitoring of the dosemeters are shown in Table 2.

All types of dosemeters have been used during the period of time under consideration, so the value of 0.1 mSv was used as the minimum detectable level, and all doses below this value have been considered as zero doses. Our estimates of annual doses on occupational exposure for cohort of the Lithuanian medical radiation workers in the periods 1950–1959 and 1960–1969 are based on data from reports in the literature[13,14] of personal badge dose records. The dosimetry data on occupational exposure for the period 1970–1990 were taken from unpublished sources of the archives of radiology departments in the largest hospitals. The dosimetry data for the last period 1991—2003 was received from RPC. Current individual monitoring for external radiation is performed at the national RPC using the RADOS Thermoluminescence Dosimetry System (TLD), Finland.

RESULTS AND DISCUSSION

The number of monitored medical radiation workers in all occupational categories increased in Lithuania (Table 3). They are similar to the data from other countries[20–24].

The working basis in the former USSR includes a period 1950–1990. The next period started in 1991,

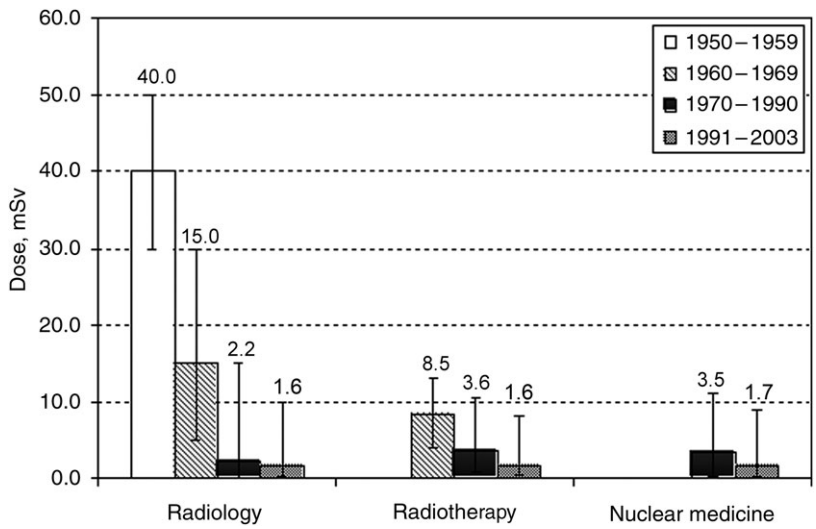

Figure 2. Annual average effective dose, mSv (min, max) for medical staff at radiology, radiotherapy and nuclear medicine departments in Lithuania, 1950–2003.

Table 4. Extremity and the highest (max) doses (mSv) in all occupational categories, 1950–2003.

Occupational categories	1950–1959	1960–1969	1970–1990	1991–2003
Radiology	NA	NA	12.7(0/0)	61.7(23/3)
Radiotherapy	NA	NA	66.7(11/3)	41.4(3/0)
Nuclear medicine	NA	NA	34.4(3/0)	11.2(0/0)

Note: In the parentheses, the number of persons with annual dose $\geq$20/50 mSv.

Table 5. The distribution (%) of the annual average effective dose by dose ranges, 1950–2003.

	$\leq$4.99	5.00–9.99	10.00–14.99	15.00–19.99	$>$20.00
1950–1959	NA	NA	NA	NA	NA
1960–1969	NA	NA	NA	NA	NA
1970–1990	85.37	5.73	5.88	0.61	2.41
1991–2003	97.38	1.77	0.50	0.13	0.22

when Lithuania became independent. The average annual effective dose steadily decreased by a factor of 3 (from 1950 to 1960), a factor of 8 (from 1960 to 1970), and was constant (from 1970 to 1991) among radiology workers; decreased by a factor of 2 (from 1960 to 1970 and from 1970 to 1991) among radiotherapy workers and decreased by a factor of 2 (from 1970 to 1991) among nuclear medicine workers in Lithuania (Figure 2).

The evaluation of extremity and highest (max) doses for medical radiation workers in Lithuania confirmed the absence of doses $>$50 mSv per year (Table 4).

However, it is possible that the recorded dose in 1970–1990 may not reflect the actual exposure, but the fact that individual dosemeters may have been sometimes left in the areas where they could be irradiated. In our case, in 1991–2003, there were three cases observed to show over 50 mSv, only among specialists of interventional radiology, where occupational irradiation is higher. Some authors propose that doses over 20 mSv should be excluded because they do not represent well-managed operation of practice[23]. All received doses were included in the analysis in our study. Table 5 presents the occupational whole-body dose distribution by dose intervals in Lithuania 1950–2003.

Against all odds in determining occupational exposures worldwide, we make an assumption that dosemeters belonging to the same periods were analogous and vary adequately from period to period.

Table 6. Annual average effective dose (mSv) worldwide, 1996–2000.

	1996	1997	1998	1999	2000	1996–2000
Norway	NA	NA	0.5	0.5	0.5	0.5
Finland	0.4	0.4	0.4	0.3	0.3	0.4
Netherlands	0.4	0.4	0.4	0.3	0.3	0.4
Lithuania	1.6	1.6	1.5	1.2	1.1	1.4
Greece	0.6	0.7	0.8	0.7	0.5	0.7
China	1.4	1.4	1.4	1.4	1.4	1.4
Poland	NA	NA	NA	1.9	1.8	NA

Considering the fact that the differences may be explained by a variety of monitoring procedures and practices, the different level of irradiation units used and different legislation of the occupational exposure in the countries[22], we have selected countries with analogous practices of TLD dosimetry, units used in same periods. We present this data in the Table 6. The occupational exposure was different among medical radiation workers in selected countries with analogous monitoring procedures and practices. For example, the study shows that in the period 1996–2000 the occupational exposure was twice as high in Lithuania and China than in Finland, Netherlands, Norway and Greece.

CONCLUSIONS

The occupational exposure of the Lithuanian medical radiation workers generally matches other published studies.

The analysis of data obtained from personal records allows to conclude that the average annual effective dose of Lithuanian medical radiation workers was greatly reduced in radiology, radiotherapy and nuclear medicine in all occupational categories from 1950 to 2003. During the last period 1991–2003, extremity doses clearly decreased and after 1994 were no longer present in Lithuania.

Although 78% of the Lithuanian medical radiation workers received individual doses below 5 mSv, the average annual effective doses were twice as high in Lithuania, China and Poland compared to other countries that were using analogous monitoring procedures and practice (TLD only) in the period 1996–2000.

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