RIGA STRADINS UNIVERSITY

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IONISING RADIATION AS AN OCCUPATIONAL RISK FACTOR IN HEALTH CARE IN LATVIA – CANCER INCIDENCE

Speciality – occupational medicine

Summary of the doctorate work

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The Thesis is available in the library and home page (www.rsu.lv) of Riga Stradiņs University.

Topicality of the problem

Occupational cancer has been in the focus of scientists for a very long time period. This is related to high levels (concentrations) of carcinogens – much higher than in environment. In addition, it has always been much easier to define study groups; therefore data on exposure have been more available.

The discovery of X-rays by Wilhelm Roentgen in 1895 and of radioactivity by Henri Becquerel in 1896 led to the development of many applications of ionising radiation. Medical use of ionising radiation started within some months after the discovery of X-rays and radioactivity (Doll, 1995; IARC, 2000). Nowadays X-rays and different radioactive sources are widely used for diagnostic examination and treatment all over the world. Medical use of radiation includes:

- diagnostic radiology (e.g., imaging, nuclear medicine);
- radiotherapy (e.g., teletherapy, brachytherapy, therapy simulations).

The first health effects developed after repeated and prolonged exposure of ionising radiation; acute damage of tissues was observed soon after discovery of ionising radiation. (e.g. a bald patch developed after trying to detect a coin through head, sore and red eyes or a painful erythema of skin after prolonged experiments). Four years after Roentgen's discovery more serious effects such as squamous carcinomas on hands of workers on the site of chronic dermatitis were described. Increased numbers of deaths from leukaemia among radiologists were reported in the 1940s. Currently, ionising radiation has been classified as a carcinogen of the 1^{st} group – carcinogenic to humans (according to the classification of the International Agency for Research on Cancer) (IARC, 2000).

Epidemiological studies of occupational exposure to radiation of early radiologists provide substantial evidence that radiation at high doses can cause leukaemia and other cancers. Due to the introduction of various radiological protection measures a tremendous decrease in doses has been observed (from many Sieverts in early radiologists to less than 1.5 miliSieverts (mSv) in measurably exposed health care workers in 1990-1994). In total altogether six independent studies have been carried out in order to evaluate cancer risk in relation to the occupational exposure to ionising radiation in health care workers, but one of the main weak points of those studies is the lack of individual dosimetric date for most of those studies. This does not allow to provide dose-response analysis. Therefore, a retrospective cohort study based on a use of data from a national register was initiated in Latvia.

Main aim and tasks

Aim:

- to evaluate occupational risk from ionising radiation in health care workers in Latvia and to analyse cancer incidence among exposed workers.

Tasks:

- to summarize data on doses of ionising radiation in health care;
- to summarize published results on cancer incidence and cancer mortality among health care workers occupationally exposed to ionising radiation;
- to investigate whether typical occupational doses of ionising radiation in health care in Latvia increases cancer risk, thus allowing to evaluate the effectiveness of occupational health and safety actions;
- to identify risk groups for cancer;
- to compare the results obtained in the survey in Latvia with the results from other countries.

Practical application

During the Soviet times and years of early independence all of the data on individual doses of ionising radiation were kept in a written form (initially these cards were kept in the Dosimetric Department of the P.Stradins clinical hospital, later in the Radiation Safety Centre of Latvia). During this study all the information was entered into the database thus made available in an electronical version. It should be pointed out that the main aim of the card system was to estimate and gather information on individual doses for exposed persons, therefore the other information in some cases was lacking or insufficient. This is the first attempt to use the data available from the National Dose Register of Latvia for a retrospective cohort study.

Most of the surveys carried out in other countries focus on evaluation of cancer risk only among males or predominantly among males, therefore mainly the data on female cancer incidence is based only on the results of the USA survey. Thus the study in Latvia presents additional information about female cancer incidence among health care workers occupationally exposed to ionising radiation, this especially applies for such gender specific cancer as female breast cancer. Additional data are available for the dose-response relationship (level of the received doses of ionising radiation in relation to cancer risk).

It should be pointed out that the data from the literature review were used for the evaluation of health effects of ionising radiation during the environmental impact assessment of building of two new radioactive waste disposal containers in Baldone region. During this assessment similar methods of the analysis as in the doctoral work were used to evaluate cancer incidence in Baldone.

In total during the preparation of the doctoral work, Linda Matisane has become a co-author of a book:

1. M.Eglīte, L.Matisāne, I.Vanadziņš. Work conditions and risks in Latvia. Riga: A/S Inspecta Latvia, 2007. - 220 pp. (topical annex “Work conditions and risks in healthcare in Latvia” is included in the attached CD of the book).

The results of the survey are presented in 3 international and 3 national conferences. 5 articles on the topics related to the doctoral work have been published, as well as 11 abstracts have been prepared:

Articles

1. M.Avota, M.Eglīte, L.Matisāne, I.Jēkabsone, E.Čurbakova, I.Vanadziņš, Z.Podniece. Objective and subjective data on incidence of occupational diseases in health care workers in Latvia, Medicina truda i promishlennaja ekologija, 2002,3:33-37 (in Russian);
2. P.Boffetta, L.Matisāne, K.A.Mundt, L.D.Dell. Meta-analysis of studies of occupational exposure to vinyl chloride in relation to cancer mortality. Scand J Work Environ Health, 2003, 29(3):220-229.
3. N.Kurjāne, T.Farbtuha, L.Matisāne. Non-malignant and malignant tumours in Chernobyl clean-up workers in Latvia. Scientific Articles of RSU; 2003; Riga, RSU, 285. -289. (in Latvian).
4. L.Matisāne, L.Carpenter, K.Venables. Female All Cancer Incidence in Medical Radiation Workers in Latvia, 1982-2002. Scientific Articles of RSU; 2004; Riga, RSU, 199. -202.
5. M.Eglīte, T.Zvagule, J.Reste, I.Bukovska, E.Čurbakova, L.Matisāne. Cancer incidence in Chernobyl clean-up workers, 1990 – 2004. Scientific Articles of RSU; 2005; Riga, RSU, 40. -46. (in Latvian).

Thesis

1. L.Matisāne, M.Avota, I.Lūse, B.Aulika. Electromagnetic fields as an occupational risk factor among health care workers. Thesis of Medical Scientific Conference of RSU 2000, Rīga, RSU, p.101.
2. M.Avota, M.Eglīte, L.Matisāne. Disease incidence and relation to occupational risk factors in health care workers – experience from Latvia. Thesis of 4th World Latvian Doctor Conference, 2001, Rīga, p.38.-39.
3. N.Kurjāne, L.Matisāne, A.Stengrēvics, E.Čurbakova. Thyroid cancer incidence in Chernobyl clean-up workers in Latvia. Thesis of 4th World Latvian Doctor Conference, 2001, Rīga, p.106.-107.
4. R.Mangule, L.Matisāne. Influence of occupational risk factors on work ability of midwifes working in Riga. Thesis of Medical Scientific Conference of RSU, 2003, Rīga, RSU, p.79.
5. A.Skujiņa, A.Zaļkalne, L.Matisāne. Radon concentration in work environment. Thesis of Medical Scientific Conference of RSU, 2003, Rīga, RSU, p.80.
6. L.Matisāne. Use of the database of workers occupationally exposed to ionising radiation as a tool for workplace risk assessment. Abstracts of 4th International Symposium "Quality in Occupational Health", Tartu, Estonia, 5-6 February, 2004, p.93-94.
7. L.Matisāne, M.Eglīte. Changes of average effective doses of health care workers in Latvia (1972-2002). Thesis of Medical Scientific Conference of RSU, 2004, Rīga, RSU, p.66.
8. L.Matisāne, M.Eglīte. Cancer incidence in female health care workers occupationally exposed to ionising radiation, 1982 – 2002. Abstracts of 3rd Nordic Conference in Epidemiology, Kuopio, Finland, June 17-19, 2004, p.66.
9. L.Matisāne. Cancer incidence in female health care workers occupationally exposed to ionising radiation, 1982 – 2002. 51st Annual Meeting of the Health Physics Society,

June 25-29, 2006, Providence, Rhode Island. http://birenheide.com/hps/2006program/singlesession.php3?sessid=P

10. L.Matisāne. Prevalence of ionising radiation as an occupational risk factor in Latvia Thesis of Medical Scientific Conference of RSU, 2007, Rīga, RSU, p.114.
11. L.Matisāne. Cancer incidence in people living near radioactive waste disposal "Radons" Thesis of Medical Scientific Conference of RSU, 2007, Rīga, RSU, p.197.

Doctoral work consists of introduction, 7 chapters, conclusions and 3 annexes of tables. There are 179 pages in the doctoral work with 136 references.

Summary of the literature review

Though ionising radiation is a well-known carcinogen, nowadays X-rays and different radioactive sources are widely used for medical purposes (IARC, 2000). It is estimated that about 2.32 millions of health care professionals are occupationally exposed to ionising radiation all over the world, and it is the largest group of workers (about 50%, in some countries up to 95%) exposed to man-made sources of ionising radiation (UNSCEAR, 2000a).

Exposure to radiation during medical use involves exposure not only of patients but also technical staff and physicians. Their exposure, like those of patients, can be categorized into irradiation from diagnostic procedures (exposure to X-rays) and therapeutic procedures (mainly exposure to γ-rays and β-rays, in rare cases exposure to neutrons during boron neutron capture therapy), but usually technicians are less exposed than patients because of shielding of the source, limited duration of exposure and greater distance (IARC, 2000). Therefore, the dose received during the procedure is diffuse (i.e. a secondary radiation is received), thus workers are exposed to irradiation of the whole body (Nemiro, 1983).

Occupational groups, which are potentially exposed to radiation, including health care radiation workers, are monitored with personal/individual dosimeters on regular basis. It is one of the most important measures in assurance of the adequacy of radiation protection. The doses usually are monitored and registered in order to assess the individual occupational protection in accordance with the national law. In Latvia such data are gathered in the National Dose Register, which is maintained by the Radiation Safety Centre.

Currently two main literature sources are available to compare dosimetric data of occupational exposures (review of these data is available in the doctoral work, in this summary, the mentioned data are used for comparison):

- the United Nations Scientific Committee on the Effects of Atomic Radiation - UNSCEAR - provides a world-wide review every 5 years;
- European Study of Occupational Radiation Exposure - ESOREX - was carried out between 1997 and 2000).

In order to provide information on long-term effects of exposure to low doses of fractionated ionising radiation, several epidemiological studies on health care workers had been carried out and the results had been published. Altogether eight independent cohort studies were identified from the United Kingdom and Ireland (one common study), USA (radiation technicians, radiologists), Japan, China, Denmark, Canada, Finland and Bulgaria. Some other related case-control studies and register-based studies were identified and used for interpretation of the results of the doctoral work.

Ionising radiation in health care is used more and more often; new diagnostic and treatment procedures are implemented on regular basis. Thus within last ten years the number of different investigations based on use of ionising radiation has increased, therefore the number of exposed personnel has increased. Although data and information is not available, it is supposed that those types of exposure differ from the types of exposure in early stages of use of ionising radiation in medicine. It is also most probably thet health effects differ from the early effects (Yoshinaga, 2004). Modern medical equipment is produced using the most effective protective systems, but the results of this study and other published results point out the necessity to continue studies on cancer incidence and mortality in health care workers who are chronically occupationally exposed to fractionated low doses of ionising radiation.

3. Materials and methods

3.1. Evaluation of prevalence of ionising radiation as an occupational risk factor

For the evaluation of prevalence of ionising radiation as an occupational risk factor the results of the surveys – inquiries of employers, employees and socially unprotected persons, were used. These surveys were carried out within the study "Work conditions and risks in Latvia" which was one of 13 surveys of the European Union Structural Fund National Programme "Labour Market Studies" project "Studies of the Ministry of Welfare".

Employers' inquiry

The target group was employers in Latvia, i.e. owners of the companies or the representatives of the top management. As the survey method Computer Assisted Telephone Interviews (CATI), specialized ad hoc interviews were used. Respondents could choose between Latvian and Russian languages. Sampling was done, using a combined method – using quota and stratified random sampling methods. The general population was around 54 600 companies (institutions) in whole Latvia (data of the Central statistical Bureau, December 2005), bet the size of the sample was 1058 companies (institutions). The analysis was done using statistical software SPSS 11.5 for Windows.

Employees' inquiry

The target group was employees and self-employed persons in Latvia. As the survey method Computer Assisted Personal Interviews (CAPI), direct interviews in the residence places of respondents were used. Respondents could choose between Latvian and Russian languages. Sampling was done, using a combined method – using quota and stratified random sampling methods. The general population was around 1 400 000 employees and self-employed persons (data of the Central statistical Bureau, December 2005), bet the size of the sample was 2455 employees and 65 self-employed persons. The analysis was done using statistical software SPSS 11.5 for Windows.

3.2. Evaluation and analysis of exposure and cancer incidence

Identification of cohort members

In order to become a member of a retrospective cohort, the health care worker have had:

1. worked in an out-patient department or hospital;
2. been occupationally exposed to ionising radiation in Latvia;
3. been registered for at least 1 year and 1 day in the national Dose Register in Latvia between 1972 and January 1, 2002;
4. worked as diagnostic or therapeutic radiologists (higher medical education), radiation technician (e.g. radiotechnician, medical nurses), nurses, junior nurses.

1972 was used as an inclusion criterion as this was the year when a totally new monitoring system of ionising radiation in work environment was introduced. This system was based on individual thermoluminiscent dosimetry. In total, between 1972 and January1, 2002 2287 persons were registered in the National Dose Register in Latvia. 413 or 18.06% were registered as radiologists, 913 or 39.92% - as radiotechnicians, 511 or 22.34% - as nurses, 231 or 10.10% - as dentists, 175 or 7.65% - as junior nurses, 44 or 1.93% - as others or information was not available. There were 1976 females (86.40%) and 311 males (13.60%) among the registered persons. In further analysis part of the registered persons were not included in analysis, as they did not satisfy exclusion criteria (e.g. work only in military hospitals, dentistry etc.).

Follow-up of cohort members

The cohort members were followed for vital status (and emigration) from the date of first employment until death, emigration, or the end of the study (31 December 2002), whichever occurred first. The vital status and the lacking personal identification numbers were checked at the Population Register of the Office of Citizenship and Migration Affairs. This Population Register includes information on family name (previous family names in case of any changes), given names, personal identification numbers, date of birth, place of birth, link to family members (children, parents etc.) and where available also place of residence.

Main problems in tracing people were as following:

- changes in personal details (e.g. of surname - usually woman change their surname at marriage and as this is a predominant female cohort this fact was one of the biggest problems);
- accuracy of the names (e.g. random transcription errors, inaccurate handwriting);
- well-known problems with variants of surnames and given names (e.g. Irēna – Latvian name, Irīna – Russian name);
- lack of consistency in the transliteration between the Cyrillic and Latin alphabets (e.g. the Russian surname Jakovļevskaja in Latvian could be written in both types - Jakovļevska and Jakovļevskaja.

In total in the Population Register 1623 persons were followed; it was not possible to identify 93 persons. This creates 94.58% identification level (this is a bit lower than in other health care cohorts (97-99%)) (Yoshinaga, 2004). In accordance to the data of the Population Register 28 persons had emigrated, but 153 persons had died.

Dosimetric data

The Laboratory of Thermoluminiscent Dosimetry provides measurements that allow to assess doses of external irradiation on quarterly basis and summarizes annual doses in individual cards / histories. Such measurements have been available since 1972 when a dosimetric department was established in the P.Stradins clinical hospital. Since 2000 this dosimetric department is included in the structure of Radiation Safety Centre. In 2002 55% of persons registered in the Register were employed in medicine (doctors, radiotechnicians, nurses, junior nurses and other persons excluding dentistry and veterinary medicine) and additional 19% were employed in dentistry (RDC, 2003).

Recalculation of doses

After analysis of dosimetric data in dynamics, it was concluded that there was not any linear reduction in the registered doses as it had been expected (caused by the implementation of the protection measures and improvement in medical equipment). Therefore, it was decided to recalculate the registered doses due to several reasons:

1. all doses reported before 1997 were reported in mR. Thus recalculation was performed in order to report all data in mSv;
2. between 1972 and 2002 several different laboratory procedures and methods had been used for detection of the doses.

The most important changes were done between end of 1988 and end of 1989 and this had been related to the exchange of equipment and procedure. Thus a recalculation coefficient was used to recalculate doses registered before 1989. The mean annual doses of 1985, 1986, 1987 and 1990, 1991, 1992 were used to calculate the average annual doses before and after changes in the laboratory, the years of 1988 and 1989 were excluded. The ratio between the above-mentioned average doses was calculated and used as a recalculation coefficient (1.71). This recalculation method was used after consultation with researchers in the Oxford University, which have had done a study on cancer mortality in British radiologists (Berrington, 2001).

Cancer incidence

Individual data on persons included in the study (given name, name of the father (where available), family name, personal identification numbers (where available), date of birth were linked with the Cancer Registry to identify cancer cases and the date of first diagnosis. In the database all cases were recoded according to the 10th revision of the International Classification of Diseases (ICD-10); codes in the previous revision format were converted prior to inclusion in the database.

The follow-up time included period between 01/01/1982 and 31/12/2002, altogether resulting in 22444.58 person-years at risk. Standardised incidence ratios (SIR) and 95% confidence interval (CI) were computed using age-, gender-, and calendar year- specific cancer rates from the Latvian State Cancer Register and statistical software STATA 8 (Stata, 2003).

In order to calculate SIR, the number of observed cancer cases were compared with number of expected cases, which was calculated from the cancer incidence numbers in population, taking into account age-, gender-, and calendar year- specific cancer rates in population. These data were available from the State Cancer Register (Baltiņš, 2003; LOC, 1994; LOC, 1996; LOC, 1998; LOC, 2002). If the number of observed cancer cases was close to the expected number, the SIR was close to 1. If SIR < 1, the observed number of cancer cases was lower than the expected number; but if the SIR > 1, the expected number was lower than the observed number.

Analysis was carried out for the whole group, as well as using different surrogate measures (like time since first employment with ionising radiation, length of exposure, age at first employment with ionising radiation etc.) Additional analysis was carried out for the sub-groups according to cumulative effective dose, calculated basing on the data of the National Dose Register of Latvia. This last analysis was carried out only for 983 subjects who were first employed in 1972 or after, as it was not possible to calculate cumulate effective dose for persons employed before 1972 due to the lack of dose registration.

4. Results

4.1. Prevalence of ionising radiation in work environment – results of surveys

Employers' survey

According to the results of the employers' survey of project "Work conditions and risk in Latvia", ionising radiation was one of the rarest occupational risk factors in Latvia. In total, only 32 employers (1.4%) had pointed out that workers in their companies at some extent are exposed to ionising radiation. Most often those respondents represented health care establishments (16 respondents or 29.4%).

Employees' survey

In order to find out the opinion of employees, they were asked a question: "Could you please tell at want extent are you exposed to ionising radiation?" The results of the survey revealed that 179 respondents (or 7.5%) at some extent were exposed to ionising radiation. 14 respondents (0.6%) had mentioned that they were exposed all of the working time, 15 (0.6%) – almost all of the time, 7 (0.3%) - around ¾ (75%) of allof the time, 11 (0.5%) – around half of the time, 27 (1,1%) - around ¼ (25%) of all of the time, 105 (4.4%) – almost never. If the analysis was provided for industries which the respondents represented, most often ionising radiation was mentioned in health care (31 respondent or 23.6%). 2 respondents (1.5%) had mentioned that they were exposed to this risk factor all of the working time, 2 (1.6%) - around ¾ (75%) of all of the time, 1 (0.7%) – around half of the time, 10 (7,4%) - around ¼ (25%) of all of the time, 16 (12.4%) – almost never.

4.2. Doses received by exposed persons

Number of exposed persons

People working in health care belonged to the biggest group of people occupationally exposed to ionising radiation in Latvia. Along with changes in economical situation the percentage had changed from 74% to 87%, and this was one of the highest levels in all of the European countries. Similarly high number had been observed in Estonia in 1997 (88%), but the highest number had been observed in Island (Frasch, 1998; Ruga, 1998; LEA, 2002).

The number of exposed people depended on the development of technologies in the world and incoming of new technologies into Latvia, but the data on time before 1972 were not available. Number of people and the doses received by them are shown in table No 4.2.1.

Table No 4.2.1. Number of monitored persons and mean effective doses (registered and recalculated, 1972. -2001.

Year	Number of monitored persons	Mean registered effective doses* (mSv)	Recalculated mean effective doses* (mSv)
1972	106	2.85	1.67
1973	92	2.77	1.62
1974	74	4.94	2.89
1975	144	3.60	2.21
1976	202	4.11	2.40
1977	230	3.23	1.89
1978	251	3.04	1.78
1979	275	3.34	1.95
1980	392	4.33	2.53
1981	483	5.48	3.10
1982	711	4.85	2.84
1983	792	4.54	2.65
1984	802	3.82	2.23
1985	800	4.14	2.42
1986	892	3.95	2.31
1987	856	4.32	2.53
1988	858	4.10	2.40
1989	828	2.32	2.32
1990	891	2.41	2.41
1991	887	2.58	2.58
1992	805	2.25	2.25
1993	760	2.25	2.25
1994	694	2.05	2.05
1995	661	2.29	2.29
1996	669	2.11	2.11

Year	Number of monitored persons	Mean registered effective doses* (mSv)	Recalculated mean effective doses* (mSv)
1997	660	1.88	1.88
1998	657	1.29	1.29
1999	692	1.31	1.31
2000	713	1.23	1.23
2001	717	1.23	1.23

Received doses of ionising radiation

Until 1981 a common trend in the dose pattern cannot be observed (see table No 4.2.1.). The reasons for that could be the fact that starting with 1972 a new system of individual dosimetric monitoring was introduced, and over the first years people were not aware of proper use of dosimeters and personal protection. The number of monitored people was quite low, so in case of several high doses, the average dose also increased more.

The highest average annual effective dose had been observed in 1981; later a decrease in annual doses had been observed and during the last 5 years it has been stable between 1.23 and 1.31 mSv. According to UNSCEAR 1990-1994 data, average annual effective dose for monitored workers in medicine had been 0.33 mSv and for measurably exposed workers - 1.39 mSv (world estimate)(UNSCEAR, 2000a).

The minimal detection limit had not been yet introduced in Latvian and the distribution of annual doses showed the biggest numbers in the dose bands of 0.5–1 mSv, 1-2 mSv and 2-5 mSv, thus more reliable comparison could be obtained if the Latvian data were compared with the annual average effective dose for measurably exposed workers. Both reported and recalculated annual doses in Latvia (1990-1994) were higher than the world estimate. The reasons for higher results in Latvia could be the old equipment in health care establishments, which still until nowadays were used in health care. Though no precise data were available for the mentioned time period it should be pointed out that in 2001 some equipment since 1968 still had been used and the percentage of the old equipment had been much higher in 1990-1994 (LEA, 2002).

Another explanation for the difference could be the fact that the response of the dosimeter to natural background level had not been taken into account when reporting the results. Usually this signal was subtracted from the actual dosimeter reading before recording, but this practice had not yet been implemented in Latvia (UNSCEAR, 2000a).

In addition it should be mentioned that sometimes workers placed the dosimeters in a radiation field in order to record higher doses as in few cases employers had been providing benefits to radiation workers especially during the Soviet times and early years of transition (for example, shortened working hours, extra vocations etc.) (Morkunas, 2001).

4.3. Cancer incidence

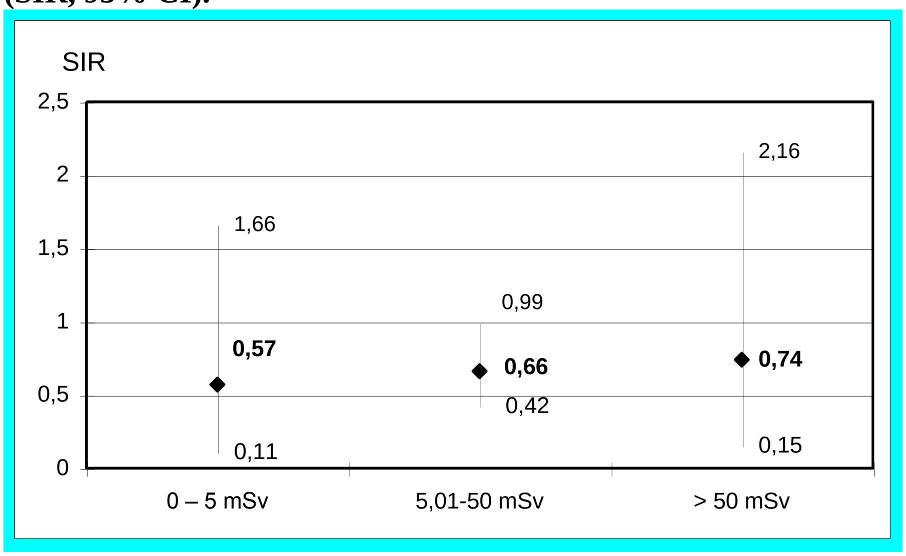
<u>Females</u>

SIR for all cancers combined was 0.76 (70 cancer cases, 95% CI 0.59-0.96) that pointed out that the number of observed cancer cases was smaller than the expected number. It could be explained by the fact that persons still employed with ionising radiation in 2002 were included in the analysis. This meant that healthy persons (proved healthy through compulsory medical check-ups) were included in the analysis thus resulting in healthier exposed group than general population. In order to get rid of this effect, additional analysis was provided for persons having left work with ionising radiation before January 1, 2002 (two or more quarters there had been no reported doses). 831 individuals were included in this analysis. The calculated SIR for this group was 0.96 (70 cancer cases versus 72.71 expected, 95% TI 0.75-1.22).

SIR for the group of persons employed before 1972 was 0.84 (433 subjects, 41 incident cancers, 95% CI 0.60-1.14). The SIR for persons first employed in or after 1972 was 0.67 (983 subjects, 29 incident cancers, 95% CI 0.45-0.97). Taking into account that the received doses in early periods were higher than in later periods, it should be concluded that cancer incidence was higher for the period when the doses of ionising radiation had been higher.

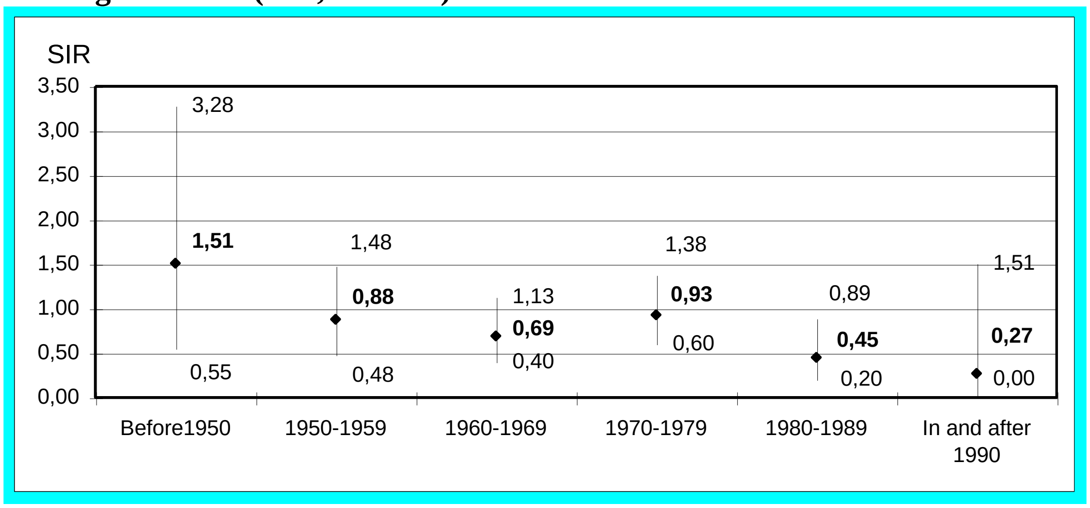
During the survey a sub-cohort of women was analysed for which dosimetric data were available. The lowest cancer risk was observed for women with lowest received doses (see graph 4.3.1.).

Graph 4.3.1. Female cancer incidence in relation to the received dose of ionising radiation (SIR, 95% CI).



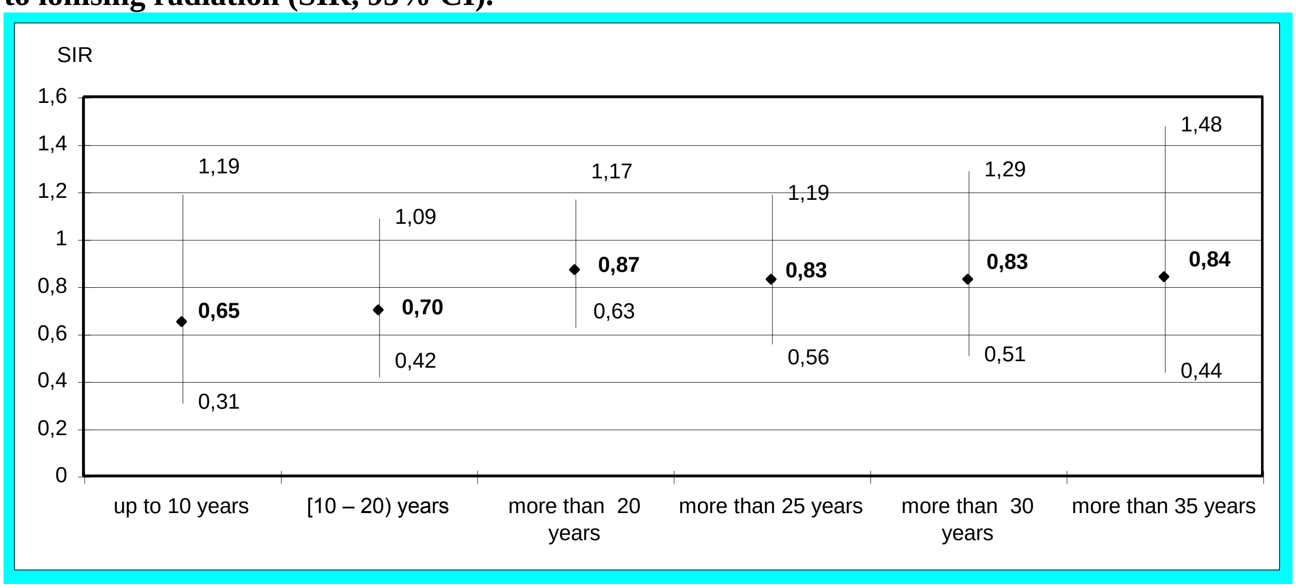
Another, but this time non-specific parameter indicating the level of irradiation was used to assess cancer risk for workers of ionising radiation. This parameter was the year first employed in work with ionising radiation. The highest SIR was observed for females who had started to work with ionising radiation before 1950 (see graph 4.3.2.).

Graph 4.3.2. Female cancer incidence in relation to time period with first employment of ionising radiation (SIR, 95% CI).



Another surrogate measure total length of occupational exposure to ionising radiation was used. The results of the survey show that SIR increased along with increase of length of service (see graph 4.3.3.).

Graph 4.3.3. Female cancer incidence in relation to total length of occupational exposure to ionising radiation (SIR, 95% CI).



As an interesting fact the following results should be pointed out – if the length of the service increased over 20 years, SIR did not increase any more – there was almost no difference between SIRs of sub-cohorts with length of service of 25, 30 and 35 years (see table No 4.3.1.).

Table No 4.3.1. Female cancer incidence in relation to the length of occupational exposure to ionising radiation (SIR 95% CI).

Length of exposure	Number of subjects	Observed cases	Expected cases	SIR	95 % CI
≥25 years	327	29	34.92	0.83	0.56 – 1.19
≥30 years	211	20	23.98	0.83	0.51 – 1.29
≥35 years	119	12	14.21	0.84	0.44 – 1.48

Additional analysis was performed, taking into account age of the person at which she had started to work with ionising radiation. SIR for all persons who had started to work with ionising radiation younger than 40, SIR was 0.71 (1154 individuals, 49 cases, 95% CI 0.53-0.94), but for persons who were older – 0.92 (262 individuals, 21 cases 95% CI 0.57-1.41). The results show that age at first employment modified cancer risk – higher the age was, higher the risk was.

If analysis was provided by two parameters combined (age at first exposure to ionising radiation and time since first employment), the highest SIR was observed for those females who were older than 40 at first employment and this work had started before 1972 (see table No 4.3.2.).

Table No 4.3.2. Female cancer incidence in relation to age at first exposure and time period first employed with ionising radiation (SIR 95% CI).

Age at first exposure	Time period	Number of subjects	Observed cases	Expected cases	SIR	95 % CI
≥40	First employed before 1972	55	8	7.87	1.02	0.44 – 2.00
≥40	First employed in 1972 or after	207	13	14.86	0.87	0.47 – 1.50
<40	First employed before 1972	378	33	40.96	0.81	0.55 – 1.13
<40	First employed in 1972 or after	776	16	27.89	0.57	0.33 – 0.93

Analysis for specific cancers also was carried out, but the low number of observed cases for specific cancers did not allow obtaining significant results, and they could be influenced by chance. Results on site specific cancers are shown in table No 4.3.3., but further analysis and assessment of the results was done only for those cases where the number of observed cases was highest or there had been discussions in literature on the possibility to link cancer risk with occupational exposure to ionising radiation in health care (especially if the exposure is low, chronic, fractionated doses).

Table No 4.3.3. Female cancer incidence by types of cancer.

Site	ICD-10	Observed cases	Expected cases	SIR	95 % CI
All sites	C00-97	70	91.84	0.76	0.59 – 0.96
Lip oral cavity and pharynx	C00-14	2	0.96	2.08	0.23 – 7.52
Nasopharynx	C11	1	0.06	16.67	0.22 – 92.73
Other lip	C14	1	<0.01		
Gastrointestinal	C15-26	9	22.21	0.41	0.18 – 0.77
Stomach	C16	3	7.32	0.41	0.08 – 1.20
Colon	C18	3	5.59	0.54	0.11 – 1.57
Rectum	C20	1	3.82	0.26	0.00 – 1.46
Liver	C22	1	1.02	0.98	0.01 – 5.45
Pancreas	C25	1	2.94	0.34	0.00 – 1.89
Respiratory	C30-39	7	4.29	1.63	0.65 – 3.36
Lung	C34	6	3.78	1.59	0.58 – 3.45
Other respiratory*	C38-39	1			
Skin melanoma	C43	3	1.78	1.69	0.34 – 4.92
Skin except melanoma	C44	7	7.51	0.93	0.37 – 1.92
Soft tissues	C49	1	0.72	1.39	0.02 – 7.73
Female breast	C50	20	21.23	0.94	0.58 – 1.46
Female genital	C51-58	15	22.48	0.67	0.37 – 1.10
Vulva*	C51	1			
Cervix uteri	C53	3	5.02	0.60	0.12 – 1.75
Corpus uteri	C54	7	9.11	0.77	0.31 – 1.58
Ovary	C56	4	7.23	0.55	0.15 – 1.42
Kidneys	C64-65	2	3.44	0.58	0.07 – 2.10
Brain and other nervous	C70-72	1	1.50	0.67	0.01 – 3.71
Thyroid	C73	1	1.51	0.66	0.01 – 3.68
Other endocrine	C74-75	1	0.11	9.02	0.12 – 50.58
Multiple myeloma	C90	1	0.80	1.25	0.02 – 6.95

* Population data on cancer incidence are not available.

The highest SIR was observed for skin melanoma, respiratory cancers, and female breast cancer. Although cases of melanoma and breast cancer were observed more often than in population, it should be pointed out that the results were based on small number of cases.

SIR for skin melanoma was 1.69 (3 observed cases, 95% CI 0.34–4.92). Two out of three cases were diagnosed for females who had started to work with ionising radiation before 1972 (SIR=2.47 95% CI 0.28 – 8.91).

SIR for respiratory cancer was 1.63 (7 observed cancer cases, 95% CI 0.65–3.36). The biggest part of the respiratory cancers was compoused by lung cancers (SIR=1.59, 6 cancer cases, 95% TI 0.58-3.45). If the analysis was provided for the sub-cohort that had started to work with ionising radiation in 1972 or later, the SIR was observed to be higher (SIR=2.21, 3 observed cases, 95% CI 0.44–6.45). In the sub-cohort for persons first employed with ionising radiation before 1972, SIR was 1.25 (also 3 observed cases, 95% CI 0.25–3.65).

For female breast cancer SIR was 0.94 (20 observed cases, 95% CI 0.58-1.46). Significantly higher SIR for breast cancer was observed in the group of females first employed with ionising radiation before 1972 (SIR=1.17, 11 observed cancer cases, 95% CI 0.58 – 2.09).

If the analysis was provided for other skin cancers except melanoma, cancer risk was close to 1 (SIR = 0.93, 7 observed cases versus 7.51 expected cancer cases, 95% CI 0.37 – 1.92).

Taking into account literature data on cancers caused by exposure to ionising radiation, most often attention was paid to so-called radiogenic leukaemia (i.e. leukaemia where one of the risk factors is ionising radiation – acute lymphatic, acute myeloid and chronic myeloid leukaemia). The results of the study in Latvia showed that only one case of haematopoietic system was observed – myeloma case (SIR=1.25, 95% CI 0.02–6.95).

As another radiogenic cancer, malignant thyroid diseases should be mentioned. Only one cancer case was observed in Latvia; the resulting SIR was 0.66 (95% CI 0.01–3.68).

Males

In the Latvian cohort males created a very small part of the cohort members – in total only 207 individuals complied with the inclusion criteria, therefore the number of observed cancer cases was small and, most probably, the results were chance findings.

The SIR for all cancers combined was almost the same for males as for females - SIR=0.73 was based on 14 cancer cases, 95% CI 0.40–1.22 (see table No 4.3.4.). The highest risk was observed for skin melanoma (SIR=4.55, 1 observed cancer case, 95% CI 0.06–25.29) and other skin cancers, except melanoma (SIR=3.42, 4 observed cancer cases, 95% TI 0.92 – 8.75). As the results were based on small number of cases, they could present chance findings and there was no necessity for further meaningful analysis, although the observed SIRs were high.

Table No 4.3.4. Male cancer incidence by types of cancer.

Site	ICD-10	Observed cases	Expected cases	SIR	95 % CI
All sites	C00-97	14	19.25	0.73	0.40 – 1.22
Lip oral cavity and pharynx	C00-14	0	0.96	0.00	- 3.82
Nasopharynx	C11	0	0.03	0.00	- 122.27
Other lip	C14	0	<0.01		
Gastrointestinal combined	C15-26	4	5.77	0.69	0.19 – 1.77
Oesophagus	C15	1	0.40	0.03	0.03 – 13.91
Stomach	C16	0	2.24	0.00	- 1.64
Colon	C18	2	0.92	2.17	0.24 – 7.85
Rectum	C20	1	0.80	1.25	0.02 – 6.95
Liver	C22	0	0.27	0.00	- 13.59
Pancreas	C25	0	0.92	0.00	- 3.99
Lung	C34	1	5.25	0.19	0.00 – 1.06
Skin melanoma	C43	1	0.22	4.55	0.06 – 25.29
Skin except melanoma	C44	4	1.17	3.42	0.92 – 8.75

Site	ICD-10	Observed cases	Expected cases	SIR	95 % CI
Soft tissues	C49	0	0.04	0.00	- 91.70
Prostate	C61	2	1.63	1.23	0.14 – 4.43
Kidneys	C64-65	0	0.84	0.00	- 4.37
Urinary bladder	C67	1	1.23	0.81	0.01 – 4.52
Brain and other nervous	C70-72	0	0.30	0.00	- 12.23
Thyroid	C73	0	<0.01		
Other endocrine	C74-75	0	<0.01		
Hodgkin's lymphoma	C81	1	0.04	25.00	0.33 – 139.10
Multiple myeloma	C90	0	0.11	0.00	- 33.35
Other					

5. Discussion

In total ionising radiation in Latvia was considered to be a rare occupational risk factor, which mainly could be found in health care where it had been used both for diagnostic procedures and treatment. Thus health care was the industrial branch where the highest numbers of employees were occupationally exposed to ionising radiation. In addition it should be pointed out that there was one major difference between the survey cohort in Latvia and cohorts with the some exposure in other countries – the majority of cohort members in Latvia was females (this applied for all of the sub-groups – radiologists, technicians, nurses and junior nurses).

5.1. All cancer incidence

Data on cancer incidence were available from 4 other studies, but before the comparison of the results, some of the differences between studies should be pointed out. The results of the study in USA (radiotechnicians)(Sigurdson, 2002), Denmark (Andersson, 1991), Finland (Jartii, 2006) and Canada (Yoshinaga, 2004) were presented as SIR (similarly to the situation in Latvia where the observed number of cancer cases were compared with the corresponding rates calculated from the population). The diagnosis had been reported in accordance to different revisions of the International Classification of Diseases and Causes of Death (ICD) (Denmark – a modified ICD-7, USA and Canada – ICD- 9, but Latvia – ICD-10) and the diagnosis were grouped using different criteria or not giving data on grouping – e.g. skin cancer. In addition, the numbers of the observed cancers in China were compared with the results calculated from the control group – other doctors (Wang, 2002). The above-mentioned things had created problems for comparison of the results of different countries.

The SIR for females for all cancers combined in Latvia was 0.76 (70 observed cancer cases, 95% CI 0.59-0.96); this showed that during the follow-up period less cancer cases were observed in the cohord comparing with the calculated numbers from the general population. Although this number was the smallest among all of the cohorts studying cancer risk from occupational exposure to ionising radiation, the trend was similar to the study results in Canada where the observed number of cases was significantly lower than expected (869 observed cancer cases, SIR=0.86, 95% CI 0.80–0.92) (Yoshinaga, 2004).

The SIR for males for all cancers combined in Latvia was almost the same as for females - SIR=0.73. It was based on 14 observed cancer cases (95% CI 0.40–1.22). SIR in

Latvia was lower than in the US study (radiotechnologists) where the calculated SIR was 0.94 (884 observed cancer cases, 95% CI 0.89-1.00) (Sigurdson, 2003), but it was higher than among males in the Canadian cohort (SIR=0.64, 561 observed cancer cases, 95% CI 0.59–0.70) (Yoshinaga, 2004). The survey in China showed that relative risk for exposed males was elevated (RR=1.24, 95% CI 1.15-1.34), but it should be pointed out that the observed number of cases was compared with a control group (other health care professionals) instead of comparing with numbers calculated from the population rates.

The observed numbers of cancer cases for both – males and females were lower than expected from the population rates and there could be several explanations for that fact. For example, one of the explanations was a slightly lower number of traced cohort members in Latvia than in other countries (in Latvia – 94.58%, in other countries - 97-99%) (Yoshinaga, 2004). At the same time this difference 2-4% did not significantly influence the results of the survey. As another probable explanation, the so-called healthy worker effect should be mentioned. The healthy worker effect is a general, but not well-defined term applied to the deficit of both morbidity and mortality ascribed to various employment-associated factors when workers and the general population are compared. The term was first used by McMichael *et al*., and it reflected the fact that an individual must be relatively healthy and active to be employable in an industrial workforce, suggesting the fact that in an industry free of significant life-shortening hazards, death rates within the workforce will be less than in the general population (McMichael, 1974).

The Industrial Disease Standards Panel has reviewed the issue of the healthy worker effect, suggesting that it consists at least of several of components, including also information bias and confounding bias (Choi, 1992). All of the seven components were evaluated also in the study in Latvia; the components, which can be observed in this study, are described in table 5.1.1.

Table No 5.1.1. Healthy worker effect in the cohort of health care workers in Latvia.

No.	Type of effect / subtype of the effect	Probability of the effect in Latvia*	Remarks
1.	**Worker healthier effect** Worker healthier effect is the true effect of work on health through physical exertion better access to medical services in case of employer's benefit programs healthy lifestyle promotion by occupational health services restrictions of smoking in workplaces and ability to purchase goods for example medical care which altogether protect them from getting diseases (Choi, 1992; McGeoghegan, 2001).	+	– better access to the health care as the cohort members are health care workers; – better knowledge about health and risk factors.
2.	**Healthy hired effect** Healthy hired effect or population selection effect refers to the initial self-selection or selection by employers of healthy individuals	+	Compulsory pre-employment medical check-ups

No.	Type of effect / subtype of the effect	Probability of the effect in Latvia*	Remarks
	(using pre-employment medical examination) into a workforce (Carpenter, 1990; Skelcher, 2001).		
3.	**Healthy worker survivor effect** Healthy worker survivor effect refers to the retention in the workforce of the healthy individuals or conversely the selective removal from the workforce of the sick (Carpenter, 1990).	+	Compulsory periodical medical check-ups
4.	**Tracking error** Tracking error can arise because of an incomplete follow-up if it has not been possible to determine the status of every subject (alive / dead ill with/ free of the disease living in the country / emigrated etc.) thus continuing to add time at risk (Arrigghi, 1993).	+/-	Probable – around 3-5% as the tracking level in Latvia was lower than in other health care cohorts (94.58% in Latvia; 97-99% in other cohorts) (Yoshinaga, 2004).

*+ - Probable
+/- - Hard to evaluate

5.2. Cancer incidence in relation to received doses of ionising radiation

Most of the surveys on health care workers occupationally exposed to ionising radiation did not have individual dosimetric data, which allowed provision of proper risk assessment (Yoshinaga, 2004). Therefore, these surveys provided analyses using indirect parameters, which were mainly related to the historical development of roentgenology (IARC, 2000).

The results from the survey in Latvia presented additional data that carcinogenic effect of low fractionated chronic doses of ionising radiation depended on length of exposure (UNSCEAR, 2000b). SIR was higher in those groups where length of work with ionising radiation was higher (length of service up to 10 years – SIR = 0.65; 10-20 years – SIR = 0.70; more than 20 years SIR = 0.87). The mean cumulative dose in cohort in Latvia was 20.66 mSv; and it was higher than in all other health care cohorts (Andersson, 1991; Ashmore, 1998).

It should be pointed out that during the follow-up period a quality management system had not been introduced in the laboratory that provided dosimetric measurements for individual dosimeters. This decreased the level of precision of the results. Additional bias could be created through recalculation of doses. It should be stressed that SIR obtained in the study in Latvia increased along with the increase of cumulative dose of ionising radiation. Thus the results from the study in Latvia provided additional data that carcinogenic effect of low fractionated chronic doses of ionising radiation in health care workers depended on life-time cumulative dose (UNSCEAR, 2000b). Additional evidence could be obtained from non-specific parameters of doses – e.g., SIR was highest in the group of workers who had started to work with ionising radiation earlier (during the period when the used equipment and protective measures were not sufficient to provide effective protection and the received doses of ionising radiation were assumed to be higher).

The results from the study in Latvia provided additional data that carcinogenic effect of low fractionated chronic doses of ionising radiation in health care workers depended on age at first exposure to ionising radiation (UNSCEAR, 2000b). The results of the study show that the cancer risk increases with increase of age at first exposure. SIR for persons who started to work before age of 40 was 0.71, but SIR for persons older than 40 years – 0.92. Similar results had been obtained also from other studies that allowed concluding that age at first exposure to ionising radiation modified cancer risk (Richardson, 1999; Wing, 2005). In Latvia cancer risk depended on combination of two factors – the cancer risk was especially elevated for persons who were older at first exposure and who had received higher doses of ionising radiation.

5.3. Specific cancer incidence

As one of the most often discussed specific cancers, female breast cancer should be mentioned. It had been proved in the international literature that doses received by females during early years of roentgenology could cause development of breast cancer (Yoshinaga, 2004). Although the number of observed cases was lower than expected (20 observed cancer cases versus 21.23 expected, SIR=0.94, 95% CI 0.58-1.46), it was higher than SIR, which was obtained for all cancers combined (SIR=0.76, 95% CI 0.59–0.96). These results showed that exposure to ionising radiation could cause increased risk of development of female breast cancer. Additional data that proved this hypothesis could be obtained from comparison of the results of sub-cohorts. The highest SIR was observed in the group of females who were first employed with ionising radiation before 1972. These results were similar to the published results showing that high doses of ionising radiation could cause development of female breast cancer (Doody, 2006).

In the study in Latvia SIR for skin melanoma in exposed females was observed to be 1.69 (3 observed cancer cases, 95% CI 0.34–4.92). Two of three cases were diagnosed in females who had started to work before 1972 (SIR=2.47, 95% CI 0.28–8.91). Furthermore, even higher risk of skin melanoma was observed in males (SIR=4.55, 1 observed cancer case, 95% CI 0.06–25.29). In US study 207 melanoma cases were observed – 193 cases were primary case and 14 were secondary cases (SIR=1.59, 95% CI 1.38-1.80) (Freedman, 2003; Sigurdson, 2002). Melanoma risk was elevated in workers first employed with ionising radiation before 1940 (RR=8.6, 95% CI 1.0-72.7). Also work for more than 5 years before 1950 was related to elevated melanoma risk (RR=2.4, 95% CI 0.7-8.7). According to the results of the National Dose Register of Canada, SIR for melanoma was increased in males (117 observed melanoma cases, SIR=1.21, 90% CI 1.03-1.41) (Sont, 2001). At the same time it should be pointed out that significantly increased SIR was observed in such sub-cohort as dentists, which had received the lowest doses of ionising radiation (SIR and CI in the publication were not given). Other surveys of health care workers did not provide data on skin melanoma and non-melanoma skin cancers separately – they paid attention either to non-melanoma skin cancer or to all skin cancers combined. Additional data on melanoma in health care workers could be obtained from the studies, which had different structure. Thus, during a case-control study of the American Cancer Society's Cancer Prevention II Study (Pion, 1995) elevated melanoma risk was observed for dentists – males (15 cases, odds ratio (OR) 2.01, 95% CI 1.04-3.88). If analysed melanoma risk according to various environmental exposures, only exposure to X-rays had shown to increase the risk significantly (OR=1.37, 95% CI 1.12-1.67). Increased risk for melanoma had also been observed in a Danish study of health care workers based on a register linkage (Rix, 1996). Male dental practitioners, female hospital doctors and nurses had significantly high risks of melanoma of the skin and these authors also attributed it to behaviour related to sunlight exposure. Another analysis the incidence of skin melanoma according to occupation had used data from two national cancer registries (Sweden and England and Wales) (Vagero, 1990). An elevated melanoma risk had been observed for both sexes in dentists (incidence ratio 2.07, 95% CI 1.33-3.09). Thus in total the results from the study in Latvia provided additional data that low and medium high fractionated chronic doses of ionising radiation can increase melanoma risk in health care workers.

Similarly to the data available on female breast cancer, it had been proven that high doses of ionising radiation can cause skin cancer - squamous skin cancer has been observed in place of chronic dermatitis (Yoshinaga, 2004; Doll, 1995; IARC, 2000). In some studies increased number of skin cancer cases have been observed in persons having worked in earlier periods (Yoshinaga, 2004). After analysis of non-melanoma skin cancer cases, it turned out that the results were not unequivocal. SIR for females was close to 1 (SIR=0.93), but for males it was elevated (SIR=3.42). Data on non-melanoma skin cancer were available from the Chinese study where 18 cases were observed versus 4.45 expected (RR=4.05, 95% CI 2.40-6.39) (Wang, 2002). The USA study (radiotechnologists) observed 1355 basal-cell cancers and 270 squamous cancers. Elevated relative risk was observed for basal-cell cancers in the sub-cohort of persons first employed before 1950 (RR=1.42, 95% CI 1.12-1.80), during forties of 20th century (RR=2.04, 95% CI 1.44-2.88) and before 1940 (RR=2.16, 95% CI 1.14-4.09). Elevated risk for squamous cancer was not observed (Rajaraman, 2006). Although the results of several studies provided information that exposure to ionising radiation can increase skin cancer risk, it is not possible to affirm that relationship between ionising radiation and development of non-melanoma skin cancer is confirmed.

5.4. The limitations of the Latvian study

Some very important limitations could be observed in the Latvian study, e.g. extremely small cohort of males resulting in small number of observed cancer cases, therefore it was impossible to obtain significant results in so short follow - up period. Therefore, although results were calculated also for males, they did not add any valuable information on cancer risk from occupational exposure to ionising radiation. This especially applied to the specific cancers, where in most cases only one or several cancer cases were observed. This had resulted in the fact that it was impossible to provide interpretation of the results of specific cancer sites which had been pointed out to be one of the most important topics in scientific literature on cancer risk in health care workers occupationally exposed to ionising radiation (Yoshinaga, 2004). Several methods had been suggested to overcome this problem – e.g. increase the size the cohort, increase length of the follow-up, as well as to provide meta-analysis for several studies (dos Santos Silva, 1999). It was impossible to use the first suggestion (to increase the size of the cohort) in Latvia, as already all of the persons complying with the inclusion and exclusion criteria were included in the study cohort. This method could be used only in case, if after some time a similar study will be repeated, both increasing the size of the cohort by persons who will be registered in the National Dose Register after 2002 and increasing the period of follow-up. But it should be stressed that the new cohort members will be exposed to lower doses of ionising radiation and will have been worked with more modern technologies as the current cohort. The other suggestion – to increase the follow-up time should be used after some time to identify cancers diagnosed after December 31, 2002. In order to obtain meaningful results, such repeated study should be done not earlier than after 10 years. Almost all of the studies published in the literature on cancer in health care workers exposed to ionising radiation had been structured in the same way – new data had been obtained after periodical expansion of the follow-up time. As a very typical and good example the combined UK and Ireland cohort of registered radiologists should be pointed out as the last publication presented data on 100 years of follow-up. This had resulted in inclusion of the whole lifetime of all individuals registered in the latest group; thus all other obstacles for interpretation of the results had been excluded - like too short follow-up period. This follow-up had been long enough to identify all cancer cases (Berrington, 2001; Yoshinaga, 2004).

Increasing of the follow-up period and inclusion of new cohort members are important also because there is a neccessity to evaluate the cancer risk for extremely low occupational doses of ionising radiation, paying special attention to the use of such new methods as computer tomography (Yoshinaga, 2004).

Although the study in Latvia was structured in accordance to the suggestions published in the literature (in order to obtain data where it is possible to analyse cancer risk in relation to received doses of ionising radiation, the survey should be based on state registers), the study in Latvia did not allow to analyse data in relation to doses of ionising radiation (Boyle, 1997; Zielinski, 1997; Yoshinaga, 1998). This was related to fact that individual dosimetric data before 1972, when the new system of individual dosimetry was introduced in Latvia, had not been available. In order to overcome this problem several methods were used – dose-response relationship was calculated for those cohort members where dosimetric data for the whole working period were available (they have started to work in or after 1972). In addition, several indirect parameters were used like time since first employment with ionising radiation, total years worked with exposure to ionising radiation etc. This meant that one of the disadvantages of the study was lack of the possibility to provide dose-response relationship for cancer risk in health care workers occupationally exposed to ionising radiation in Latvia.

Conclusions

1. The survey on cancer incidence in health care workers occupationally exposed to ionising radiation was the first occupational epidemiological study in Latvia which had tried to combine the results from two national registers – the National Dose Register of the Radiation Safety Centre and the Latvian Cancer Register. This pointed out that it was and stll is possible to carry out similarly structured studies in future (e.g. for analysis of specific occupational exposures using databases of companies etc.).
2. Ionising radiation as an occupational risk factor should be regarded as a rare risk factor in Latvia, but health care should be mentioned as an industrial branch where the highest number of exposed persons are working.
3. If compared the cohort structure of Latvia with other health care cohort, a huge difference was observed – the biggest part of cohort members in Latvia were females (this applies for all sub-groups – radiologists, radiotechnicians, nurses and junior nurses). This is an important health risk, but it is mainly related with pregnancy and the probable irradiation of foetus during pregnancy.
4. Cancer incidence in health care workers in Latvia occupationally exposed to ionising radiation was lower than in population. It was supposed that this was mainly related to well-known healthy worker effect. In Latvia several components of the healthy worker effect were observed, mainly related to better access to health care than general population, pre-employment and periodical compulsory medical check-ups etc.
5. Cancer incidence in both sexes in Latvia was observed to be very close, but a very low number of cancer cases were observed in males, therefore it was impossible to obtain significant results. It is advisable to repeat the study with the same cohort after 10 to 20 years; therefore the person-time at risk will increase (IARC, 2000).

6. The results of the Latvian study pointed out that age at first occupational exposure to ionising radiation modified cancer risk – higher the age was, higher the cancer risk was.
7. Received doses of ionising radiation directly influenced cancer risk. This could be proved by direct and indirect parameters:
    a. SIR was the highest in the groups where the received doses were the highest;
    b. SIR was the highest in the group of workers who had started to work with ionising radiation during the earliest period (e.g. during the period when the used equipment and protective equipment did not provide sufficient protection resulting in higher doses than those received during the later periods);
    c. SIR was the highest for the group of workers who had worked with ionising radiation for the longest period;
    d. SIR was the highest for doctors – radiologists than for radiotechnicians and nurses (the mean annual effective doses was higher for radiologists than for other sub-groups).
8. Along with the increase of total length of work with exposure to ionising radiation over 20 years, cancer risk did not increase any more – SIR did not differ in groups of workers with total length of exposure more than 25, 30 and 35 years.
9. The study results from Latvia showed that cancer risk depended not only from the length of exposure, but also from age at first exposure, in addition the risk even more depended on the combination of both of the mentioned risk factors – older the worker had been at first exposure and having worked for longer period, the cancer risk was higher.
10. There were limitations for interpretation of the results on specific cancer sites in relation to ionising radiation due to the low number of observed cases.
11. When specific cancer incidence for females was analysed, elevated SIR was observed only for skin melanoma, respiratory cancers and female breast cancer.
12. When specific cancer incidence for males was analysed, elevated SIR was observed only for skin melanoma and other skin cancers except melanoma.
13. The results of the survey in Latvia presented additional data to the previously published results that chronic low fractionated doses of ionising radiation can increase risk of such specific cancers as female breast cancer and skin melanoma for both sexes.
14. The results of the survey in Latvia provided additional data to the published hypothesis that greater sensitivity to low fractionated chronic doses of ionising radiation could be observed at older age – age at first exposure modified cancer risk by increasing it (UNSCEAR, 2000b).
15. Along with changes of technologies used in health care, changes in exposure patterns also can be observed, but data on cancer risks related to new occupational exposures are not yet available. Therefore, it is extremely important to provide additional follow-up for existing cohorts and add new cohort members to the mentioned cohorts.

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