

Radiation epidemiological studies in the Russian National Medical and Dosimetric Registry with respect to Chernobyl accident: II. Assessment of radiation risk of cancer and non-cancer diseases, 1986-1999

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More than 13 years passed after the largest in the history of humankind technological catastrophe at the Chernobyl NPP. Estimation and prediction of radiological consequences of the catastrophe is one of the key problems on choosing optimal strategy for long-term rehabilitation actions. The most sensitive indicator for radiation effect is well known to be excess induction of malignant neoplasm's, mainly such as leukemia. International Commission on Radiological Protection (ICRP) and other international organizations provided assessments of radiation risks for excess mortality from malignant neoplasms derived from long-term epidemiological studies of the cohort of atomic bomb survivors of Hiroshima and Nagasaki. The assessments are based on direct epidemiological studies within the range of intermediate and high radiation doses (above 0.3 Sv). At a low radiation dose level (less than 0.2 Sv), which is characteristic of the Chernobyl accident, radiation risks were estimated by extrapolation and should be justified by epidemiological data. Russian National Medical and Dosimetric Registry (RNMDR) was established after the Chernobyl accident. As of 01/01/1999, the Registry has kept individual data on 531 thousand persons. The Registry consists of two basic groups of initial of registration, such as: liquidators (32.9%) and residents of the most contaminated with radionuclides areas of Russia (57.7%).

In 1998 radiation risks for induction of malignant neoplasms for the follow-up from 1986 to 1996 were assessed on the basis of individual data on the cohort of liquidators registered at RNMDR. Previously we have published coefficients for radiation risk for the follow-up from 1986 to 1994 (Radiat. Environ. Biophys., 1997; Health Phys., 1998). The basic results of the study performed in 1998 are as follows: ERR/Gy for leukemia excluding CLL is 9.9 (95% CI: 1.1, 18.6); it is 0.9 for solid malignant tumors (95% CI: 0.3, 1.6). Mean external radiation dose to liquidators is 0.11 Gy. So, statistically significant coefficients for radiation risks for malignant neoplasms at low radiation doses were resulted from direct epidemiological study.

Results of an analysis of thyroid cancer incidence in the territories of Russia most contaminated after the Chernobyl accident are given. In this study data on incidence in the Bryansk, Kaluga, Orel and Tula regions (5,240 thousand persons) are used.

For the analysis, 3,082 (age of 0-60 years) cases of thyroid cancer are considered from 1982 to 1996. Of them, 78 cases were among children and adolescents and 178 among the population who were children and adolescents at the time of the accident in 1986.

Excess absolute risk (EAR) was assessed with the use of reconstructed doses to the thyroid of exposed children and adolescents (age of 0-17 years) of Bryansk region. Cases detected over the period 1991 to 1996 were taken in the study. Dose-risk linear relationship was obtained. EAR is 2.21 (95% CI: 0.74, 3.68) per 10^4 PYGy for girls and 1.62 (95% CI: -0.04, 3.23) per 10^4 PYGy for boys.

A dependence of risk of cancer on age at exposure has been derived. For children of 0-4 years at exposure the risk of induction of radiogenic thyroid cancer is 14 times higher than in adults. On the average, the risk coefficient in children and adolescents at the time of exposure is about 2.3 times higher than in adults.

The paper presents results of estimation of radiation risks in the cohort of children from the Kaluga region of Russian Federation exposed to radioiodine in 1986 as a result of the Chernobyl accident. This work was carried out under the Joint Medical Research Project on non-cancer thyroid diseases conducted by Sasakawa Memorial Health Foundation and MRRC of RAMS. By the end of 1998 the Kaluga part of the cohort including 2005 people was completed. All members of the cohort have individual radiometric thyroid data obtained between May and June 1986. All the subjects were under 10 year old at the time of exposure. Analysis of the results has shown that the distribution of absorbed doses of internal exposure to the thyroid is close to lognormal distribution with a mean value of 55 mGy and standard deviation 69 mGy. The maximal dose is 1.1 Gy. The estimation of excess relative risk (ERR/Gy) has revealed statistically significant ($p < 0.05$) dose response in induction of non-cancer thyroid diseases for Goiter nos (code ICD-9: 240.9) among children of 2-4 years old at the time of the Chernobyl accident.

Introduction

In June of 1986 (in two months after the Chernobyl catastrophe) Ministry of Health of the USSR and Academy of Medical Sciences of the USSR made decision on setting up All-Union distributed registry (AUDR) for persons exposed to radiation. Research Institute of Medical Radiology of Academy of Medical Sciences of the USSR (now it is Medical Radiological Research Center of Russian Academy of Medical Sciences) was designated as heading institution responsible for setting up and managing AUDR.

The staff of the institute have two basic tasks:

- Prompt information support for making managerial decisions at the level of the Ministry of Health of the USSR towards minimization of consequences of the catastrophe;
- Support for long-term radiation-epidemiological studies and identification of radiation and non-radiation factors modifying risk (similar work was performed within frames of the registry of atomic bombing survivors in Hiroshima and Nagasaki).

The registry operated until 01/01/1992 (time of dissolution of the USSR). Information on 659 thousand individuals exposed to radiation including 285,000 recovery workers of the Chernobyl catastrophe had been collected and analyzed.

At present time Russian National Medical and Dosimetric Registry (RNMDR) is operating at MRRC RAMS (Obninsk) under Enactment of the Government of the Russian Federation N 948 of September 22, 1993 and Orders of the Ministry of Health of The Russian Federation and Russian Academy of Medical Sciences. Individual information on 531 thousand persons including 174 thousand emergency accident workers ("liquidators") is stored at the registry.

Leukemia and solid cancer incidence in emergency workers of the Chernobyl accident: risk estimates

Risk for radiation-induced cancers is maximal for leukemia; latent period for it is minimal, 2 years [1]. The first analysis for leukemia radiation risks for liquidators of Russia was made in 1996 [2, 3]. In paper [2] authors applied cohort technology to the study, the population of Russia stratified by sex and age was chosen as control group. Information on 48 leukemia cases among male liquidators detected over 1986-1993 was analyzed. Excess of leukemia incidence

among liquidators over control is statistically meaningful. Standardized incidence ratio for liquidators is 1.5 (95% CI: 1.1, 2.0). The risk of radiation-induced leukemia was assessed on the assumption that the excess was caused by radiation. Magnitude of excess relative risk (ERR/Gy) is 4.3 (95% CI: 0.8, 7.8).

In paper [3] authors used case-control technology. In the study statistically meaningful risks were not found, however the tendency towards relation of relative risk to dose was shown.

In the presented work the analysis of new data on leukemia incidence among liquidators is given. For the period over 1993-1996 distribution of leukemia cases by various reasons has changed: newly diagnosed cases and newly reported cases were added, diagnosis for some cases and date of its ascertainment was verified. Detected number of leukemia cases allow us to analyze them with the use of the most reliable medical and dosimetric data. In the analysis medical and dosimetric data from 6 regional centres of Russia (Severo-Zapadny, Volgo-Vyatsky, Povolzhsky, Centralno-Chernoziomny, Severo-Kavkazsky and Uralsky) were used.

The size of the cohort under study is 9,3849 individuals, of them 68,199 persons have authorized doses recorded in documents.

Number of person-years for the period of follow-up was 903,230 (648,917 PY with authorized doses). Mean dose to a liquidator with authorized doses is 0.11 Gy. Mean age at arrival at 30-km zone around the Chernobyl accident is 32.4 years.

To estimate the coefficients for radiation risk of leukemia incidence. 22 cases with verified diagnosis were considered. Individual doses of external exposure to these cases are kept at RNMDR. Set of data used for estimation of coefficients for risks by methods of maximal likelihood is given in Table 1.

At present time chronic lymphatic leukemia (CLL) were not proved can be caused by radiation. That is why all types of leukemia except for CLL (5 cases) were taken in the study of dose-response relationship. Data used for calculation of risk coefficients are given in Table 2.

Relationship between incidence rate and dose is shown in Figures 1, 2. Estimates for risk coefficients for all types of leukemia are shown in Table 3.

Obtained results show that coefficients for risk for all types of leukemia are not meaningful. When CLL is set off risk coefficients is statistically meaningful.

Table 1
Set of data used for estimation of dose-response relationship for leukemia incidence (all types of leukemia)

Dose group	Number of PY of follow-up	Number of cases	Mean dose (Gy)	Mean age of cases		Mean age of all liquidators	
				At exposure	At diagnosis	At exposure	At diagnosis
1	154,226	5	0.02	32.6	37.0	34.5	42.7
2	211,726	5	0.08	31.9	39.1	34.8	43.4
3	170,453	6	0.16	31.9	39.5	34.9	44.2
4	111,074	6	0.23	35.6	44.4	34.3	43.9

Table 2
Set of data used for estimation of dose-response relationship for leukemia incidence (except for CLL)

Dose group	Number of PY of follow-up	Number of cases	Mean dose (Gy)	Mean age of cases		Mean age of all liquidators	
				At exposure	At diagnosis	At exposure	At diagnosis
1	365,952	7	0.05	31.7	38.4	34.7	43.1
2	170,453	5	0.15	35.6	42.2	34.9	44.2
3	111,074	5	0.23	34.2	43.3	34.3	43.9

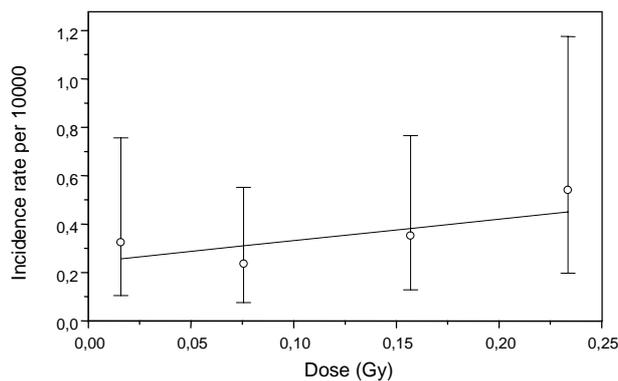


Fig. 1. Dose-response relationship for leukemia incidence (all types of leukemia) among liquidators.

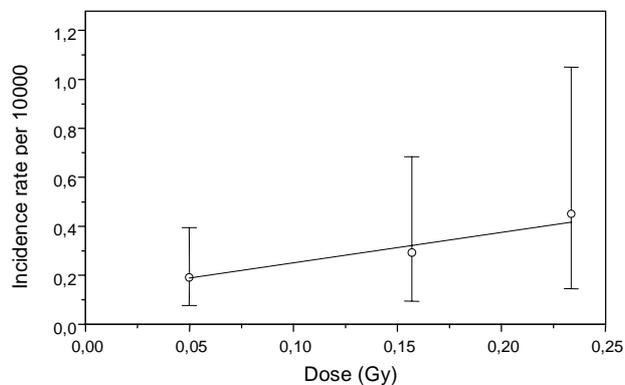


Fig. 2. Dose-response relationship for leukemia incidence (except for CLL) among liquidators.

Table 3
Estimates for risk of radiation-induced leukemia in cohort of liquidators

Risk	All types of leukemia (95% CI)	All types of leukemia except for CLL (95% CI)
EAR [10^4 PY Gy] ⁻¹	0.9 (-0.3, 2.0)	1.2 (0.1, 2.3)
ERR/Gy	3.7 (-1.7, 8.4)	9.9 (1.1, 18.6)

Estimation of radiation risks

for solid cancers

The cohort study was used for analysis of solid cancer incidence among liquidators. Cohort of liquidators under study consisted of 160564 persons.

The distribution of liquidators in relation to dose of external exposure (cGy) is given in Table 4.

The mean age of liquidators at arrival at the zone around Chernobyl NPP is 34 years. The majority (80%) of liquidators took part in recovery work over 1986-1987 [4].

Figure 3 shows estimates for relative risk (RR) for all solid cancers. RR is ratio of incidence rates within some dose range to that attributed to the dose group of 0-5 cGy. Values for ERR/Gy for malignant neoplasms of digestive organs and abdominal, as well as respiratory organs and breast are given in Table 5.

ERR/Gy > 0 is shown for all three classes of disease. However, ERR/Gy exceeds 0 meaningfully for the class "all solid cancers" only, for two other classes meaningful dose-response relationship is not found.

Table 4

Distribution of liquidators in relation to dose of external exposure

Total number	160,564	100%
Without dose	40,094	24.97
[0-5]	38,566	24.02
[5-10]	30,412	18.94
[10-15]	11,973	7.46
[15-20]	13,501	8.41
[20-25]	20,753	12.93
[25+]	5,265	3.28

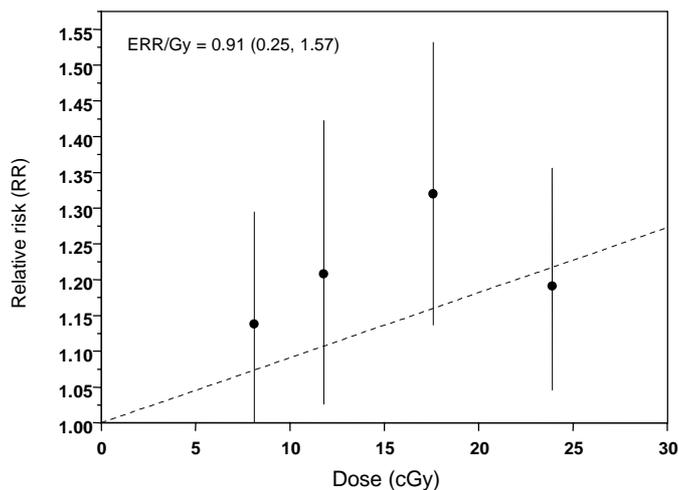


Fig. 3. Estimates for relative risk (RR) for all solid cancers among liquidators (95% CI).

Table 5

ERR/Gy estimates (95% CI) for several classes of malignant neoplasms

Classes of disease	Code (ICD-9)	ERR/Gy	Level of meaningful
All solid cancers	140-165.9, 170-195.8	0.91 (0.25, 1.57)	0.01
Malignant neoplasms of digestive organs and abdominal	150-159.9	0.85 (-0.3, 2.04)	0.2
Malignant neoplasms of respiratory organs and breast	160-165.9	1.13 (-0.24, 2.4)	0.14

Risk of radiogenic thyroid cancer in Russia following the Chernobyl

accident

According to the results of studies performed in

Russia, the Ukraine and Belarus after the Chernobyl accident essential increase in thyroid cancer incidence in the contaminated with radionuclides areas has occurred. One of potential causes of the growth is exposure of thyroid in the residents of the contaminated areas to incorporated iodine-131 (¹³¹I). This problem is particularly urgent for those residents of the contaminated areas who were children and adolescents during the exposure, as the risk of developing cancer (as well as dose) is strongly dependent on the age at the exposure.

Results of analysis of thyroid cancer incidence in the territories of Russia most contaminated after the Chernobyl accident are given. In the work data on incidence in the Bryansk, Kaluga, Orel and Tula regions (5240 thousand persons) are used [5].

The dynamics of thyroid cancer incidence in the study regions in comparison with Russia is presented in Figure 4. Figure 4 presents a standardized inci-

dence ratio (SIR) with 95% confidence intervals (SIR = observed number of cases/expected number of cases) for all four regions altogether. The dynamics of SIR in 1982-1996 in the four regions reveals an interesting feature. Indeed, in 1982-1986 the thyroid cancer incidence, both in males and females, was lower than in Russia (Russia as a whole is taken as control). In 1982-1986 SIR less than 1. In the second period 1987-1991 SIR, on the average, is more than 1 (1.6 times higher), i.e. the incidence in the four regions becomes higher than in Russia as a whole. As the period 1987-1991 is a latent period in radiation induction of thyroid cancer, the growth of incidence in this period can be attributed to introduction of a specialized examination system in these regions (the screening effect). After 1991 a certain growth of thyroid cancer incidence in the four regions of Russia under the study is observed.

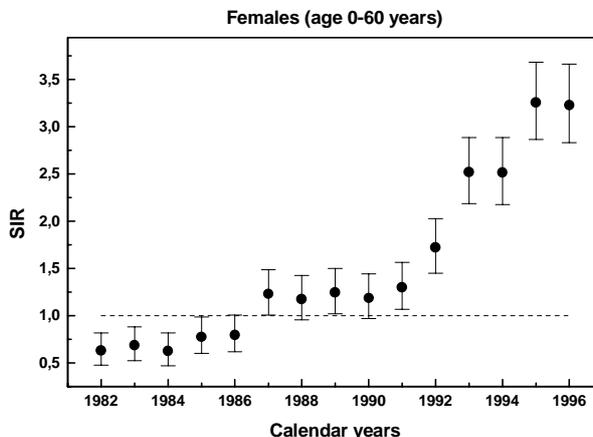


Fig. 4. Dynamics of standardized thyroid cancer incidence ratio in the four regions under consideration together (control - Russia).

Figure 5 presents results of calculating risk of radiation-related thyroid cancer in children and adolescents with respect to adults with 95% confidence intervals. It can be seen that the relations for girls in the period of spontaneous cancers are close to unity and differ significantly from unity in the assumed period of development of radiation-induced cancers (1991-1996) for children and adolescents.

The points on the plot are shifted to reveal the bias in the values. As is seen from Figure 5, the relative risk of development of radiation-induced cancer for girls of 0-4 years of age at exposure is 14 times and for those of 5-9 years - 5 times higher than the risk for adults in the considered period 1991-1996. On the average, the risk coefficient in children and adolescents at the time of exposure is about 2.3 times higher than that in adults.

Figure 6 shows the relationship between incidence rate of thyroid cancer among girls exposed to radiation at the age of 0-17 years and the thyroid dose in Bryansk region. 48 cases diagnosed over 1991-1996

were analyzed. All doses were divided into 8 dose intervals; the width of the interval was matched by criteria of homogenous distribution of number of persons and cases. Median interval dose is calculated with the account for the weigh of the size of age group of the population laying in a dose interval.

From the Figure 6 it is seen that dose-effect curve is close to line. It fits up-to-date ideas on existence of relationship between dose and thyroid cancer. Excess absolute risk EAR (angular coefficient of the relationship) is 2.21 (95% CI: 0.74, 3.68) per 10⁴PY Gy. Relative risk (ratio of EAR to the incidence rate at zero dose) is 7.3 (95% CI: 2.4, 12.1). The obtained value of EAR within confidence limits corresponds to the value of risk for children and adolescents (girls) due to exposure to incorporated ¹³¹I given in [6] - 2.5×(4/3)×(1/3)=1.1 [10⁻⁴PY Gy]⁻¹. EAR is 1.62 (95% CI: -0.04, 3.23) per 10⁴PY Gy for boys, however it is not statistically significant, may be, because of less number of thyroid cancer cases (25).

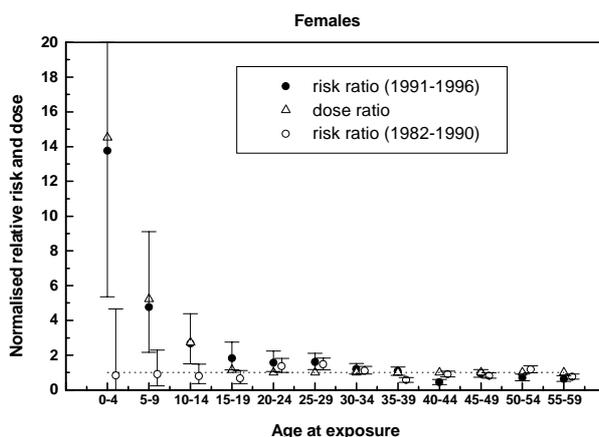


Fig. 5. Ratios of risks (*RR*) and doses (*D*) as a function of age at exposure and calendar period.

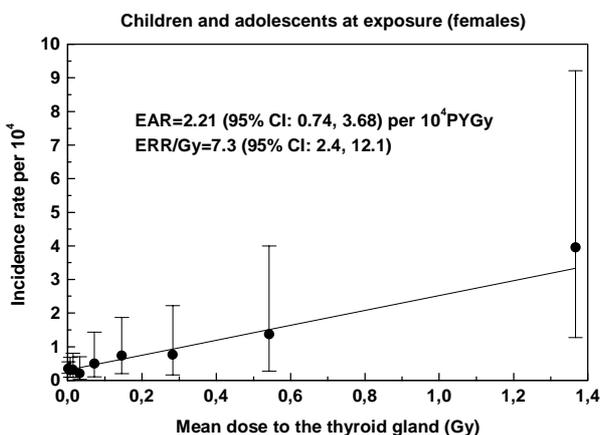


Fig. 6. Relationship between dose and thyroid cancer incidence rate among children and adolescents at the age of exposure (females) over the period of observation 1991 to 1996.

Assessment of radiation risks of non-cancer thyroid diseases

One of the most complex and topical problems related to radiation exposure and epidemiology considered by the Russian National Medical and Dosimetric Registry (RNMDR) is the dynamics of thyroid cancer and non-cancer incidence. As to the dose response of thyroid cancers, by now statistically significant radiation risks have been established both for the cohort of the emergency workers from RNMDR [2] and children (at the time of the accident) exposed most to radiation, in particular to the incorporated iodine as a result of the Chernobyl accident [5]. At the same time, the problem remains open concerning estimation of radiation risks of non-cancer thyroid pathology. The number of publications on this topic is very limited.

For example work [7] describes a study of non-

cancer diseases in the Japanese cohort AHS (Adult Health Study). The radiation risk coefficients were estimated to be: excess relative risk per Gy (ERR/Gy) 0.30 (95% CI: 0.16; 0.47); excess absolute risk per 10^4 person years Gy (EAR/ 10^4 PY Gy) is 11.96 (95% CI: 6.65; 17.34); attributive risk per Gy (AR/Gy) is 16.4% (95% CI: 9.1; 24.2). In fact, this was the first work to prove statistical significance of the dose response of non-cancer thyroid disease in the adult cohort.

In 1997 the cohort radiation-epidemiological studies of non-cancer thyroid diseases were started as part of the joint project of MRRC of RAMS and Sasaki Memorial Health Foundation. It was planned to form a cohort of children who were under 10 years at the time of the Chernobyl accident and live in two regions of Russia: Kaluga region (not less than 2000 persons) and Bryansk region (not less than 1000 per-

sons). The particular requirement was that data of individual thyroid measurements conducted in May-June 1986 were to be available for each member of the cohort.

The project will have three stages: estimation of absorbed thyroid dose from incorporated iodine for each member of the cohort; medical examination of each member of the cohort based on screening using ultrasonic instrumentation; radiation-epidemiological analysis of individual medical and dosimetric data and estimation of radiation risks in the dynamics of non-cancer thyroid pathology.

The present paper presents the main results of the joint project of MRRC of RAMS and Sasakawa Memorial Health Foundation for the Kaluga part of the cohort (the Bryansk part of the cohort has not been completed). The Kaluga part of the cohort includes 2,005 persons meeting the above requirements of age

at the time of the accident and availability of individual thyroid radiometry data.

Table 6 presents the structure of morbidity among the cohort members from the Kaluga region. The largest proportion was for the so-called "goiter n.o.s (not other specified)" (ICD-9 240.9). The study has covered diagnoses with ICD-9 codes 240.9-246.2. In-born abnormalities (759.2, 3 cases) and thyroid cancer (193.0, 2 cases) are not considered in the further analysis, while relevant persons are not excluded from the cohort.

As the background morbidity may depend upon gender, the model was added with stratification by gender.

The estimated thyroid doses depend on age (see Figure 7). That is why the excess relative risks were considered for separate age groups. Although it was also done for the whole cohort in general.

Table 6

Structure of thyroid diseases among the cohort members from the Kaluga region (Y is the number of cases)

ICD-9	Diagnosis	Both sexes		Boys		Girls	
		Y, persons	%	Y, persons	%	Y, persons	%
193.0	Malignant neopl. thyroid	2	0.62	2	2.3	0	0
240.9	Goiter nos	166	51.6	39	45.4	127	53.8
241.0	Nontoxic uninodular Goiter	39	12.1	11	12.8	28	11.9
241.1	Nontoxic multinodular Goiter	14	4.4	5	5.8	9	3.8
245.2	CHR lymphocyt. thyroidit	17	5.3	4	4.7	13	5.5
246.2	Cyst of thyroid	81	25.2	22	25.5	59	25.0
759.2	Endocrine anomaly nec.	3	0.92	3	3.5	0	0

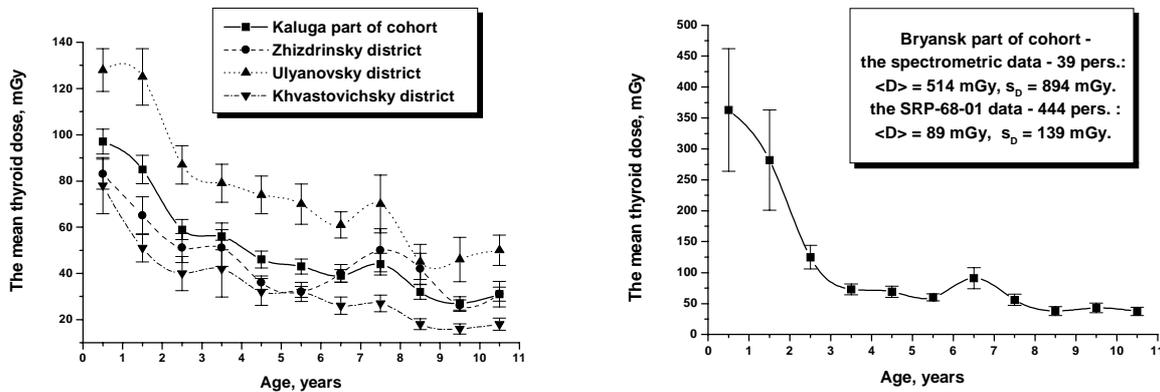


Fig. 7. Dependence of the mean absorbed thyroid dose for the cohort members on age at the time of the accident.

As the history of the cohort before 1997 was not known, the regression model for the Odds Ratio (OR) in the form of

$$OR = \exp(b_{sex}) \cdot (1 + ERR \cdot dose),$$

is used for Excess Relative Risk (ERR) assessment. The variable *dose* in this formula means the individual estimated thyroid dose and the parameter

b_{sex} characterizes background odds ratio for different sexes.

The results of evaluation by the GMB0 program of EPICURE package [8] with the default logistic sub term $\exp(b_{sex})$ [8, 9] are shown in the Tables 7-10 in the rows marked as GMB0 in the column "Program".

The analysis of ERR was also conducted with the historical cohort model with the assumption that the

cohort members were free of diseases at the time of the accident. This assumption is partly approved by the available retrospective medical data on the Zhizdrinsky district's part of the cohort (661 persons), for which 580 persons had the same medical examinations in 1986 year. From this 580 persons only 2 persons had thyroid diseases in 1986. The Poisson regression model for the incidence rate and the AMFIT

program of EPICURE [8] was used for the ERR evaluation. For decreasing the statistical scatter of individual thyroid doses 8 groups were formed: 0-20, 20-40, 40-60, 60-80, 80-100, 100-140, 140-220, >220 mGy.

The results of ERR evaluation by the AMFIT program are shown in the Tables 7-10 in the rows marked as AMFIT in the column "Program".

Table 7
Excess relative risk for non-cancer thyroid diseases with 95% confidence intervals (CI). All ages

Thyroid diseases	ICD-9	Program	All ages		
			P	ERR/Gy	95% CI
All thyroid diseases	240-246	AMFIT	0.306	1.00	(-0.50; 3.18)
All thyroid diseases	240-246	GMBO	0.426	0.94	(-0.77; 3.67)
Goiter nos	240.9	AMFIT	0.019	3.61	(0.84; 7.99)
Goiter nos	240.9	GMBO	0.037	3.69	(0.59; 8.81)
All thyroid diseases except goiter nos	except 240.9	AMFIT	0.199	-1.60	(-1.91; 0.59)
All thyroid diseases except goiter nos	except 240.9	GMBO	0.242	-0.90	(N/A; N/A)

Table 8
Excess relative risk for non-cancer thyroid diseases with 95% CI.
Age of 0-1 years at the time of the accident

Thyroid diseases	ICD-9	Program	0-1 years old		
			P	ERR/Gy	95% CI
All thyroid diseases	240-246	AMFIT	0.644	1.11	(-1.84; 8.71)
All thyroid diseases	240-246	GMBO	0.644	1.33	(-1.27; 11.11)
Goiter nos	240.9	AMFIT	0.434	2.31	(-1.55; 13.93)
Goiter nos	240.9	GMBO	0.448	2.57	(-1.34; 16.60)
All thyroid diseases except goiter nos	except 240.9	AMFIT	0.568	3.01	(-2.35; 82.59)
All thyroid diseases except goiter nos	except 240.9	GMBO	0.700	2.24	(N/A; 97.31)

Table 9
Excess relative risk for non-cancer thyroid diseases with 95% CI.
Age of 2-4 years at the time of the accident

Thyroid diseases	ICD-9	Program	2-4 years old		
			P	ERR/Gy	95% CI
All thyroid diseases	240-246	AMFIT	0.088	2.70	(0.07; 7.24)
All thyroid diseases	240-246	GMBO	0.156	2.87	(-0.30; 9.22)
Goiter nos	240.9	AMFIT	0.012	6.12	(1.44; 15.60)
Goiter nos	240.9	GMBO	0.023	7.14	(1.26; 20.52)
All thyroid diseases except goiter nos	except 240.9	AMFIT	0.291	-1.88	(-1.93; -1.80)
All thyroid diseases except goiter nos	except 240.9	GMBO	0.367	-0.91	(N/A; N/A)

Table 10
Excess relative risk for non-cancer thyroid diseases with 95% CI.
Age of 5-10 years at the time of the accident

Thyroid diseases	ICD-9	Program	5-10 years old		
			P	ERR/Gy	95% CI
All thyroid diseases	240-246	AMFIT	0.174	4.77	(-0.78; 14.13)
All thyroid diseases	240-246	GMBO	0.103	7.15	(-0.05; 20.34)
Goiter nos	240.9	AMFIT	0.934	-0.37	(-3.07; 10.89)
Goiter nos	240.9	GMBO	0.842	-0.91	(-2.84; 10.19)
All thyroid diseases except goiter nos	except 240.9	AMFIT	0.086	8.82	(0.26; 26.78)
All thyroid diseases except goiter nos	except 240.9	GMBO	0.048	12.02	(1.37; 35.74)

p - p-value of the likelihood ratio test;
Dose groups for AMFIT evaluation: 0-20, 20-40, 40-60, 60-80, 80-100, 100-140, 140-220, >220 mGy.

Tables 7-10 include results of the calculation of the excess relative risk (ERR) per Gy, which were

made by two different models - binomial odds (GMBO) and Poisson regression (AMFIT), with 95% confidence intervals (CI). The letter p stands for two-side p-value of the likelihood ratio test with respect to the zero model for which ERR=0.

The most appropriate evaluation for the goiter is done by regression model for the odds ratio (marked as GMBO) since the diagnoses of the goiter nos (ICD-9: 240.9) had unknown history before 1997 year and could be established and removed several times for one child because of the nature of this disease.

The evaluation of ERR with the model for the incidence rate obviously would have bias in this situation and tends to have smaller mean value of ERR. Nevertheless, the principal results are not depending on the model used, as shown in Tables 7-10.

As shown in the Tables 7 and 9 for the disease "goiter nos" (ICD-9: 240.9) the influence of the dose factor (ERR is not zero) is found as a significant value ($p < 0.05$) for the age group 2-4 years at the time of the accident and on the average in the cohort. For the age of 2-4 years goiter nos ERR equals 7.14/Gy as estimated by binomial odds model (GMBO). ERR equals 6.12/Gy for the less probable situation when this diagnosis was established once for child since 1986, as calculated by the Poisson regression model (AMFIT). In both cases the 95% confidence intervals are positive. It is clear from the Tables 7-10 that the goiter makes the main influence on the dose response for all non-cancer thyroid diseases. This response of course reveals the age dependence. The results of this work indicate that the age dependence of the non-cancer thyroid pathology needs to be studied and dose effects are possible to clarify, given the cohort in question is expanded.

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