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A national cancer registry to assess trends after the Chernobyl accident

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Summary

The National Cancer Registry has been operational in the Republic of Belarus since 1973: information on all new cases of malignant tumours is registered. The data are kept in a computer database and used for assessing the oncological status of the population, and for epidemiological studies. We compared findings before the Chernobyl accident of April 26, 1986 (Chernobyl) and findings between 1990 and 2000. The overall comparison on the changes in the incidence of cancer morbidity in Belarus is presented. The increase is statistically significant for all regions, but significantly greater in the most chronically radiation-contaminated region: the Gomel oblast.

The paper presents a comparative analysis of the incidence of cancer morbidity in the population of two regions of Belarus, selected for the greatest difference in their radioactive contamination following Chernobyl. The highest contamination occurred in the Gomel region and is mainly due to high levels of radiocaesium (^{137}Cs) in the soil and in the alimentary chain, especially in rural areas. A relatively low radioactive fallout was noticed in the Vitebsk region, considered here as the "control" area. We compare the situation before and after Chernobyl in the two regions. The overall cancer morbidity rate in all organs including colon, urinary bladder and thyroid, was significantly higher in the Gomel region than in Vitebsk.

In populations living in two areas with high ^{137}Cs contamination (oblast of Gomel and Mogilev), the peak incidence rates of breast cancer were already reached between the ages of 45–49 years, 15 years earlier than in the Vitebsk region.

Belarussian "liquidators" who were mobilised to clean up the most contaminated territory and build the sarcophagus around the destroyed atomic plant, received the highest radiation doses. They had a significant excess of incidence of cancers of colon, urinary bladder, and thyroid gland, when compared with a corresponding adult population of the Vitebsk region.

The Relative Risk (RR) of lung cancer among "liquidators" in 1997–2000 significantly exceeded 1, while in the control population it remained stable.

Key words: incidence of different solid cancers; Chernobyl accident; liquidators

Introduction

The Chernobyl accident (Chernobyl) resulted in negative social, economic and medical effects. Radioactive iodine and over hundred other radioisotopes were thrown out in the atmosphere, the fallout covered the whole territory of Belarus.

During the first weeks, ^{131}iodine played the leading role in the exposure of the population. Only a northern part of the country (mostly in the Vitebsk region) was relatively "clean". The rest of the territory was contaminated with 5 and more curies (Ci)/km^2. The greater part of the Gomel region, and parts of the Mogilev and Brest regions, were contaminated with more than 50 Ci/km^2 of ^{131}I. In some areas of the Gomel region, the levels of ^{131}I exceeded 300 Ci/km^2 [1, 2].

Initially, radio-iodine was responsible for high doses to the thyroid and later considered as responsible for thyroid cancer and other thyroid diseases [3, 4]. Stable iodine prophylaxis started 10 days after the accident and was useless since by that time the thyroid had already taken up huge amounts of ^{131}I.

Due to the Chernobyl accident 43500 square kilometers of Belarus were contaminated by long-lived isotopes of caesium (Cs), strontium (Sr) and transuranians. 2.1 million inhabitants (23%) of Belarus lived in the territory with ^{137}Cs level of more then 40 kBq/m^2. 7.9% of the national territory had ^{137}Cs levels exceeding 185 kBq/m^2 (5 Ci/km^2). More than 90% of such territories are located in the Gomel and Mogilev regions. According to the assessment, when the level of the soil contamination reached 100 kBq/m^2 (2.7 Ci/km^2), the average annual effective dose is 0.1–0.2 mSv [5, 6].

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In order to protect populations living in the most contaminated areas 135'000 individuals were relocated. About 120'000 citizens of Belarus were mobilised to clean up and decontaminate the area around the nuclear power plant and the 30 km zone of exclusion around Chernobyl. These workers, so-called liquidators, received the highest exposure doses. Due to unavailability of equipment, it was not possible to measure real exposure doses. Dose estimates are still a point of discussion among specialists. This fact makes it impossible to accurately estimate the prognosis of later stochastic effects of ionizing exposure and radiation risk.

According to some estimates, (including UNSCEAR 2000) up to 90% of the cumulative dose was received during the period of 1986–1995. The average individual doses received in 1986–1995 by the population living on the territories with a contamination of 37–185 kBq/m^2 (1–5 Ci/km^2) were 3.9 mSv; on the territories with 185–555 kBq/m^2 (5–15 Ci/km^2) the doses were 18.7 mSv, and with more than 555 kBq/m^2 (>15 Ci/km^2): 47 mSv. At present, the exposure dose is mainly due to internal irradiation by incorporated radionuclides, a minor proportion being due to external exposure. An excess over the permissible annual doses affects mostly the rural population [4, 6].

Materials and methods

Data of the National Cancer Registry and Registry of the subjects affected by the Chernobyl accident served as basis for this study. In 1973, the database for malignant cancers was established in Belarus, where the information on each newly diagnosed case of malignant tumour was registered. Special record forms called "Dispensary follow-up records" served as sources of information for establishing the database. These forms were filled-in and coded in the different oncology units ("dispensaries") in Belarus. At the end of each year they were sent to the Republican Oncology Institute for computer processing. Up to 1985, family names of patients were not recorded on this computer (PC) database, but the individual number of the patient was [7].

There are 12 oncology units in Belarus: 1–3 in each region. These units provide data from all oncology patients and treatment for 80% of them. In accordance with the legislation, every hospital and out-patient department has to present information of newly diagnosed cases to the local oncology unit. In each area an oncologist performs a survey of the patients, notifying the units. Such a system allows strict control over all cases of malignant neoplasia.

The majority of oncology patients in Belarus are examined and treated in oncology units or at the Republican Institute for Oncology and Medical Radiology. All information introduced into the PC memory is taken from primary medical records of the oncology units. Details from medical documents and notifications from other medical institutions where the diagnosis of malignant tumour was made (and treatment carried out) are sent to the oncology unit. Pathologists also send the oncology unit information about cases of malignant tumours confirmed at autopsy.

Thus, comprehensive information is continuously compiled which makes it possible to undertake epidemiological studies among groups of populations in Belarus affected by Chernobyl.

In 1985–1989, a PC control system of oncology units, including the follow-up of cancer patients was gradually established. The main features of the new system are:

- the use of full ICD-9 and –10 and ICD-0–2 for coding malignant tumours (site and morphological structure)
- built-in an algorithms for quality control of the information (agreement between tumour site, morphology, sex and age), developed based on the recommendations of the International Agency for Research of Cancer (IARC).

A national registry for people affected by Chernobyl collects personal data from liquidators, or subjects relocated from the contaminated areas, and of persons still living in contaminated territories. Unification of the system of the cancer registry and of the Chernobyl registry allows assessment of cancer incidence rates in these populations.

Statistical evaluation

In order to study the morbidity rates of groups according to the radioactive risk, the Vitebsk region was chosen as a control, due to its lowest chronic contamination level in Belarus. The population of this region was least affected by Chernobyl; there are only few persons living in the Vitebsk region, who were resettled from the Chernobyl areas. When analysing the morbidity rate in the control group, all cancer cases diagnosed among people who were resettled in or evacuated to Vitebsk, as well as in liquidators were excluded from the study.

Since age and sex distribution in the studied groups often differed from that of the controls, the comparative analysis of the morbidity rates was carried out using standardised indices, by the method of age-standardisation technique. When comparing the incidence in different regions of the country standardised indices calculated for age groups with 5-year intervals from 0 to 85 and older were used: for liquidators aged 20–85 years and more. TASR (truncated age-standardised rate), was also used for the estimation of thyroid cancer morbidity in the adult population, from the age of 30–85 years and older (excluding children who became adults after 1986).

While comparing the mean incidence indices for a number of years, mean of raw variation and standard errors of mean values were calculated. A significant difference in mean values was estimated using the Student criterion.

While estimating relative risk (RR) values, the liquidators, ie, the "exposed group" was compared with the "non-exposed group" from the corresponding population of the Vitebsk region, selected by using TASR technique for the analysis. Changes in the morbidity rates were assessed, using trend models [8, 10]. Age indices of breast cancer incidence were calculated for the female population of corresponding control regions.

Cancer morbidity in the population of Belarus

Though a great number of publications after Chernobyl deal with thyroid cancer in children, this well recognised malignant solid tumour does not represent more then 0.4% of the total of the cancers described here.

Table 1 shows mean standardised morbidity data and linear regression coefficients for 2 periods of time (1976–1985 and 1990–2000). In the whole republic, the average morbidity rates for all cancers increased by 39.8%, which is statistically significant (from 155.9 to 217.9 per 100'000 inhabitants).

A statistically significant increase in the morbidity was observed in all regions of Belarus, but it was most pronounced in the Gomel region, where it increased by 55.9%. From 1976–1985, the morbidity rate in the Gomel region was lower than the mean republican level. In 1990–2000, it exceeded the republican level, due to the more rapid growth in the morbidity rates as compared with other regions.

The largest increase in the regression coefficient is noted in the Gomel region: from 2.79 in 1976–1985 to 5.8 in 1990–2000. In other regions, no significant increase in the regression coefficient was calculated (Table 1).

In 1990–2000, a significant increase in the regression coefficient is recorded for the cancer of colon, urinary bladder and thyroid. In the last decade, the incidence of lung cancer decreased markedly in all regions of Belarus. At the same time, differences in the regression indices for lung cancers in Gomel region, before and after Chernobyl, are less pronounced when compared with the other regions of Belarus. In other words, in Gomel region, which is most contaminated with radionuclide, there are factors preventing a decrease of the incidence of lung cancer.

Age specific distribution of breast cancer incidence in Belarusian females living in the Gomel, Mogilev and Vitebsk regions have shown that the peak incidence rates of breast cancers in females from Gomel and Mogilev regions were reached at the age of 45–49 years, 15 years earlier than in the Vitebsk region.

The curves of the incidence depending on age, show a considerable shift towards younger age groups, which is especially marked for females living in villages of contaminated regions as compared with urban populations. But the global average incidence rate of breast cancer for the Gomel, Mogilev and Vitebsk regions did not show statistically significant increases in this period.

In the Gomel region, the collective cumulative radiological doses in the rural population are twice as high as in the urban population. The collective dose received by the rural population from 1986 to 1994 exceeds twice the dose of the urban population of the Gomel region ie, 7349 and 3656 men-Sv, respectively [4, 9].

In the population of the Gomel region, living in areas with levels of ^{137}Cs over 555kBq/m^2, an important increase in the cancer morbidity was recorded. The higher average level from 1993 to 2002 for digestive and respiratory organs is statistically significant. When comparing this group with populations living in regions with the lowest level of contamination, the average cancer incidence rates for the groups of digestive organs were respectively: 141.5 ± 8.4 and 104.7 ± 10.1, $p < 0.05$; for respiratory organs: 83.7 ± 6.0 and 53.1 ± 5.3.

The incidence of thyroid cancer

The increase in the incidence of thyroid cancer among children is indisputable. The unparalleled increase of more than 100×, is considered to be due to radioactive iodine in the first weeks following Chernobyl [3, 11].

The incidence in adults also increased, however, for a long time this increase gave rise to very little scientific interest. Before Chernobyl, thyroid cancer was a rather rare malignant disease among adults in Belarus. After 1990, the incidence of thyroid cancer sharply increased and reached the highest world rates recorded in recent years.

In 1980 the standardised index of thyroid cancer incidence among the adult population older than 30 years of age was 1.24 per 100'000. In 1990 this index was 1.96, and in 2000 it reached 5.67. Children whose age at the time of the accident was 0–14 years, moved up to the age group 15–29 years by 2000, and therefore were not included in the group of adults. Among the liquidators the standardised index of incidence for the period of 1993–2000 was 24.4 per 100'000.

Incidence of cancer morbidity in liquidators

Among liquidators, a significant increase in cancer morbidity was recorded during the period under study. The cancer incidence is significantly higher ($p < 0.05$), when compared with the adult population (more than 20 years of age) in the Vitebsk region, using the truncated standardised indices (TASR), from 1993–2000.

Table 2 shows that the global cancer morbidity rate in all sites, including the cancer of colon and urinary bladder, was significantly higher in liquidators than in the control group of the same age and sex. The increase in incidence is based on average values of annual incidence increase and linear regression rate.

Average annual excess rates of cancers in all sites in liquidators was 5.5%, which is significantly higher than in the adult population of the Vitebsk region, where it was 1.5% ($p < 0.05$). The incidence of colon cancer accounted for 9.4% in liquidators, and 3.2% in the adult population of Vitebsk region ($p < 0.05$), kidney cancer: 8.0% and 6.5% ($p < 0.05$), urinary bladder cancer: 6.5% and 3.8% ($p < 0.05$), respectively.

To estimate the variation in the increase in incidence, trend models were used. The regression coefficient analysis (a) of the morbidity changes showed a marked growing trend for the incidence of colon cancer (a = 3.4 ± 1.1) among liquidators, as compared with the adult population living in the Vitebsk region (a = 0.47 ± 0.2, $p < 0.05$), lung cancer (a = 6.7 ± 2.3, and 1.3 ± 1.5, $p < 0.05$), bladder cancer (a = 1.2 ± 0.4 and 0.25 ± 0.1, $p < 0.05$), as well as globally for all cancer sites (a = 25.2 ± 7.6 and 7.4 ± 3.2, $p < 0.05$) respectively.

Table 1

Average incidence/year for all types of cancers (in 100'000 Inhabitants, based on standardised indices, world standard). Comparison in 7 regions of Belarus, and globally in the whole country.

Region	Average incidence and standard error*		p	Regression rate and standard error*		p
	1976–1985	1990–2000		1976–1985	1990–2000	
Brest	150.1 ± 2.81	199.5 ± 2.6	<0,001	2.80 ± 0.26	2.30 ± 0.40	>0.05
Vitebsk	158.2 ± 3.24	217.9 ± 3.5	<0,001	2.60 ± 0.63	2.90 ± 0.67	>0.05
Gomel	147.5 ± 2.52	224.6 ± 6.3	<0,001	2.79 ± 0.24	5.80 ± 0.86	<0.01
Grodno	143.8 ± 3.11	207.2 ± 4.2	<0,001	2.72 ± 0.71	3.52 ± 0.79	>0.05
Minsk	145.3 ± 3.26	216.6 ± 3.9	<0,001	3.01 ± 0.48	2.77 ± 0.91	>0.05
Mogilev	166.4 ± 3.98	219.6 ± 3.1	<0,01	4.04 ± 0.45	2.80 ± 0.46	>0.05
Minsk city	223.5 ± 5.72	263.7 ± 1.76	<0,001	5.51 ± 0.25	–0.08 ± 0.58	<0.001
Belarus	155.9 ± 3.80	217.9 ± 3.4	<0,001	3.76 ± 0.32	3.15 ± 0,44	>0.05

* The regression rate (± the standard error in observation periods) is compared before the Chernobyl accident (1976–1985) and after 4 to 14 years (1990–2000). It includes all the residents in each region and the global population of Belarus.

Table 2

Incidence of different cancers among male liquidators during 1993–2000, compared with the control group of adults (Vitebsk) (TASR m per 100'000 of the population[1]).

Site	ICD IX code	Vitebsk region	liquidators
All sites	140–208	361.2 ± 6.4*	400.8 ± 7.7
Stomach	151	44.4 ± 1.2	42.1 ± 2.5
Colon	153	16.1 ± 0.6*	21.6 ± 1.8
Rectum	154	17.9 ± 0.6	19.1 ± 1.7
Lung	162	53.9 ± 1.6	56.9 ± 2.9
Skin	173	33.0 ± 1.8	28.9 ± 2.1
Breast	174	57.3 ± 0.9	59.8 ± 6.7
Urinary bladder	188	10.4 ± 0.4*	16.9 ± 1.6
Kidney	189	13.0 ± 0.9	16.2 ± 1.6

[1] TASR – truncated age-standardised rate for aged 20–85 years and older. Excluding liquidators and evacuated people from Vitebsk region.
* significant differences: all sites: p <0.001; colon: p <0.01; urinary bladder: p <0.001.

Table 3

Relative risk (RR) in the incidence of cancer of liquidators from 1997 to 2000, compared with the adults of the control group (Vitebsk). (TASR m per 100'000 of the population[1]).

Site	expected (control region)	observed (liquidators)	RR	95 % confidential level	
All sites	373.3	449.3	1.20*	1.14	1.27
Stomach	41.7	44.9	1.08	0.92	1.26
Colon	17.0	22.3	1.31*	1.03	1.67
Rectum	19.0	18.4	0.97	0.77	1.23
Lung	52.4	67.3	1.28*	1.13	1.46
Breast (female)	58.6	61.3	1.05	0.81	1.35
Urinary bladder	10.9	17.0	1.55*	1.21	1.99
Kidney	14.8	17.9	1.21	0.97	1.50

* significant differences for all sites, colon, lung and urinary bladder.
[1] TASR: truncated age-standardised rate for aged 20–85 years and older.

For other forms of cancer, no significant difference was found when compared with the control region. Among females, no statistically significant increase was recorded in cancer sites under study. The cohort of female liquidators from Belarus was only 5500.

The evolution of the incidence of stomach cancer among liquidators compared to the adult population in Vitebsk region, showed a contrary trend, which was not statistically significant (regression coefficient was 2.6 ± 1.6 among the liquidators and –1.03 ± 0.4 in the control group, p >0.05). An statistically significant increased incidence in lung cancer was observed in liquidators. In the population of the control group, the incidence of lung cancer slightly decreased (regression coefficient was 6.1 ± 2.1 and –0.73 ± 0.7 accordingly, p <0.05).

Among liquidators, living in areas with the levels of contamination of ^{137}Cs higher than 555 kBq/m^2, the mean incidence of respiratory tract cancer (larynx, trachea, bronchi and lung) was 80.1 ± 16.4, in 1993–2002, compared to 44.7 ± 7.0 per 100'000 liquidators living in regions with a contamination level equal to or below 185 kBk/m^2.

Relative Risk (RR) values were studied separately during the two periods of time (1993–1996, and 1997–2000). From 1993 to 1996 no statistically significant excess was found in cancer sites under study. From 1997 to 2000 RR significantly exceeded 1 for colon cancer, lung cancer and bladder cancer, as well as globally for all forms of solid cancers (Table 3).

Discussion

When comparing populations living in highly radio-contaminated regions with those living in "clean" regions, significant differences are noted in the incidence of cancer morbidity. The collective dose in the rural population is twice as high as in the urban population In even more irradiated subjects, such as liquidators. The increase of the cancer morbidity is even greater.

Exposure to radioactive iodine is apparently responsible for the increase in thyroid cancer in the adult population. A significant increase in adults has been recorded since 1991. The data of 1993–2000 also show an increase of this disease in liquidators.

Although a great number of publications after Chernobyl deal with thyroid cancer in children, this well recognised malignant solid tumour does not represent more than 0.4% of the total of cancers described here. The increased incidence of thyroid cancers among adults did not arouse scientific interest.

A significant increase in the incidence of cancer morbidity of colon, lung, urinary bladder and thyroid gland, as well as cancers of all sites, was observed in the population of the contaminated areas. This increase is significant in inhabitants of the most contaminated Gomel region and in liquidators. The RR for cancers in liquidators significantly increased only in recent years (1997–2000) ie, after a 12–15 year latent period. Significantly higher RR during these years was found for cancers of colon, lung urinary bladder and globally, for all sites (table 3). A significantly higher incidence of thyroid cancer was also recorded in liquidators. In the liquidators with the highest dose exposure for periods of one to several months close to Chernobyl, there is a significant increase of the incidence of the morbidity for different cancers, more marked among those who worked there for a longer a period of time.

In the adult population of the Vitebsk region, and in the global population of Belarus, there is a trend towards a decrease of the incidence of stomach cancers, whereas among the liquidators, there is an opposite trend: the increase may, in the near future, become statistically significant.

The peak incidence rates of the breast cancer was reached 15 years earlier in women of the Gomel and Mogilev regions as compared with women of the Vitebsk region. It is extremely difficult to estimate the tobacco consumption in Belarus. Therefore, it is impossible to determine if this plays a role besides radiation in the increase of lung cancers in liquidators. The higher incidence in the morbidity of cancer in the liquidators who had received the greatest doses during their work, constitutes a significantly higher risk when they live in the radio-contaminated areas of the Gomel region. In the Gomel region, the tobacco consumption had no reason to be higher among liquidators, than in other territories of Belarus.

The scientific community reads a lot about the increase of the thyroid cancer in children, considered to be a consequence of the exposure to radioactive iodine. In the adult population a 5-fold increase of incidence of this cancer was found, but this fact has not yet been reflected in documents of the IAEA, and the UNSCEAR, although we have published data showing the increased incidence in thyroid cancer in adults following Chernobyl.

According to published data on the effects of the A-bombs of Hiroshima and Nagasaki, there was a significant increase in the relative risk for cancer of colon, urinary bladder, lung, stomach and some other neoplasms, 10 to 20 years after exposure [12], showing the correlation between these tumours and ionizing radiation. Therefore, the corresponding findings after Chernobyl are not surprising.

The groups of highest risk are populations continuing to live in radio-contaminated territories and those consuming contaminated food since 1986.

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