Case-control analysis of leukemia among Chernobyl accident emergency workers residing in the Russian Federation, 1986-1993

Ivanov V.K., Tsyb A.F., Konogorov A.P., Rastopchin E.M., Khait S.E.

Medical Radiological Research Centre of RAMS, Obninsk

This paper presents an analysis of data of the Russian National Medical and Dosimetric Registry (RNMDR) on the incidence of leukemia among Chernobyl accident emergency workers (EWs) who are resident in the Russian Federation (RF) for the period from 1986 through the end of 1993. It describes the system of collection and verification of data on leukemia. The analysis deals with 48 cases of leukemia diagnosed and verified among EWs. Distributions of leukemia cases by date of diagnosis, age, radiation dose, date of entry into the Chernobyl zone, date of exit from the zone, duration of stay in the region of Chernobyl were calculated. To evaluate leukemia risks associated with various factors the case-control methodology was used. Radiation dose, date of entry into and date of exit from the zone, duration of stay in the zone were used as risk factors. No significant associations between leukemia risks and the investigated factors were found. Calculations of standardised incidence ratios (SIR) revealed a significant increase in the incidence of leukemia among EWs of all dates of entry into the zone (SIR: 205, 99% confidence interval (CI): 105-305) and EWs entered the zone in 1986-1987 (SIR: 200, 95% CI: 118-282) compared to the general male population of the RF in 1991-1993.

Introduction

The accident at the Chernobyl nuclear power plant (ChNPP) demanded great efforts to eliminate its consequences. Hundreds thousands of workers, military servants and experts of various specialties were involved in emergency and recovery works in the zone of Chernobyl. They had to work under conditions of ionizing radiation, higher physical and psychological loads. Emergency workers (EWs) received external irradiation doses predominantly from external γ-ray exposures extending up to 250 mGy, with a mean dose of 105 mGy [1]. That is why especial attention should be paid to these Ews in studies conducted to assess the carcinogenic effects of low-level radiation exposure in humans.

Epidemiological studies among the Japanese atomic bomb survivors exposed at high dose rates show that the increased leukemia risk [2] is one of the earliest and most prominent stochastic radiation effects. Moreover, an international combined study of nuclear industry workers in the United States, the United Kingdom and Canada demonstrated a significant association between mortality from leukemia excluding chronic lymphocytic leukemia and radiation dose in the combined worker population received protracted low-dose exposure to ionizing radiation [3]. Some studies confirm the fact of an increase of leukemia risk due to radiotherapeutic treatment [3, 4].

The leukemia subregistry established within the framework of the RNMDR in 1994 includes data on leukemia cases and other lymphatic and haematopoietic cancers diagnosed among EWs after their stay in the zone of the ChNPP.[1] Leukemia is one of the rarer cancers. The number of newly diagnosed leukemia cases in Russia among males aged from 20 to 59 ranges within 4-5 cases per 100 000 persons in a year. Valid complete epidemiological information on leukemia may be collected only as a result of an additional medical investigation which includes collection of primary medical documentation and materials according to a certain pattern with subsequent verification of diagnoses. This situation is explained by insufficient medical information and the system of its collection for leukemia within functioning orders of the Ministry of Health of the RF for the RNMDR[2]. It should be also stressed that in Russia the system of registration and statistical record of leukemia is characterized significantly incompleteness as a whole [5]. At present the RNMDR contains medical and dosimetric information for over 160 000 EWs residing in the RF and involved in recovery operations at the ChNPP in 1986-1990. They mainly live in cities and large districts that ensures the availability of a high level of health care and an

[1] Here and further in the article the zone of ChNPP (the Chernobyl zone, the zone of Chernobyl) is not limited by the 30-km zone around NPP, it also covers territories (settlements) more distant from NPP, where EWs lived or worked [5].

[2] The hierarchic structure of the RNMDR, the system of data collection, the format of medical and dosimetric information accumulated in the registry were described in [4].

acceptable level of verifiable data input accuracy to the RNMDR.

The article presents the results of an analysis of leukemia data in relation to EWs for the period from 1986 through the end of 1993.

Materials and methods

Study population

155,680 EWs, men[3], residing in the RF and for whom in the RNMDR there is valid information on data used in the analysis, namely, region (oblast) of residence, date of birth, date of entry in the Chernobyl zone, date of exit from the Chernobyl zone, external irradiation dose[4] were selected for the analysis from the database of the RNMDR.

The system of collection and verification of data on leukemia among EWs

For every worker included in the RNMDR and for EWs under study as well, a set of official documents containing identification, dosimetric and medical data is stored in the registry. One of these documents is the annual physical examination form which includes medical information about a worker [4]. The physical examination form is filled out for every emergency worker passed through dispensary examinations in the region of his living annually. All diseases including leukemia diagnosed in an emergency worker during a year are written in appropriate fields of the form. Twice a year the physical examination forms accumulated in regional centers of the RNMDR are transferred by means of computer files to the national level in Obninsk, where the main database of the RNMDR containing all medical and dosimetric information of the registry is formed. All leukemia cases among EWs, who at least in one the physical examination form (in the fields of diagnoses) have a leukemia code[5], are extracted from the database of the RNMDR. Then according to a designed pattern medical investigation is conducted for every case.

The necessity of this investigation is stipulated by several reasons. First, as the primary analysis of the RNMDR data on leukemia among EWs showed, in a number of cases non-leukemia diagnoses were incorrectly classified by codes referring to leukemia ones. This was caused basically by medical errors of disease coding in several regions. Taking special difficulties in diagnosing of leukemia into consideration, also we did not exclude the possibility of hyperdiagnosis of leukemia in regions. Therefore to avoid entering invalid diagnoses in the RNMDR, it was decided to verify the diagnosis for every leukemia case amongs Ews stored in the database. For this purpose medical documentation and materials confirming the leukemia diagnosis entered in the database are inquired from regions, namely, conclusion of haematologist, extract from the medical history, outpatient or inpatient cards with indication of blood and bone marrow tests, hystological conclusion on biopsy of lymphatic nodes, autopsy protocols, death certificate, the conclusion of an expert board[6], as well as diagnostic materials - blood and bone marrow slides. When all the required materials have been obtained, specialists in diagnosing leukemia from the MRRC RAMS in Obninsk critiqued the background of the diagnosis established in the region. Results of the expert judgments are sent to the regions. Only in the case of mutual positive decision made by the specialists of the MRRC RAMS and physicians from regional medical institutions where EWs are followed-up, are the diagnoses considered to be verified and they are entered in the leukemia subregistry. All the rest diagnoses are judged as unverified until other additional materials are received and repeated expertises are made, or the diagnoses are completely taken off if regional specialists agree that the established diagnoses are groundless.

Dosimetry

Dosimetry data for EWs are entered in the RNMDR on the basis of official documents such as military cards, certificates of emergency workers, certificates on work in the Chernobyl zone. These data may be divided by three main groups depending on a method used to assess an external irradiation dose:

- doses determinated using an individual dosimeter;
- group doses when one an emergency worker of the whole group, worked in the zone, had a dosimeter;
- doses reconstructed on the basis of route lists in which all movements of EWs inside the zone were registered.

Out of all EWs included in the analysis, 125317 have records of external irradiation doses. In our analysis, assuming that an error of every individual

[3] Men are about 99% of the total number of EWs.

[4] Dose is not to exceed 500 mGy but it may be unknown. All doses above 500 mGy entered in the RNMDR require additional dosimetric investigation and documentary confirmation. Therefore EWs with such doses are not included in the analysis until final dose verification.

[5] The analysis was conducted for leukemia cases with ICD-9 codes 204.0-208.9.

[6] The expert board is the regional interdepartmental expert board making a decision on causal relationship of diseases (disability) of emergency workers with their involvment in cleaning operations after the Chernobyl accident.

dose may be significantly higher than a maximal possible difference between values of an exposure dose and an absorbed dose of the whole body external irradiation, we take all doses as absorbed ones and use mGy [6] as a unit of dose measurement.

Statistical methods

The analysis was performed both for all EWs (EWs of all dates of entry in the Chernobyl zone) and for EWs worked in the zone in 1986-1987 (hereinafter EWs of 1986-1987). The separate analysis for EWs of 1986-1987 is explained by the fact that they worked in the condition of the highest radiation doses, physical, emotional loads and psychological stress, comparing with EWs of other years.

Because of the small number of leukemia cases among EWs for the discussed period, the analysis was conducted for all types of leukemia combined without consideration of differences in the nature of the dose response for the various types of leukemia, as well as without consideration of a possible latent period between an exposure and its effects - radiation-induced leukemias.

To evaluate leukemia risk associated with various factors the case-control methodology was used [7]. External irradiation dose, date of entry in the Chernobyl zone, date of exit from the Chernobyl zone, duration of stay in the zone were used as risk factors in the case-control study. Four control EWs[7] from the RNMDR database were selected for every case:

- without leukemia;
- alive at the moment when the case was diagnosed;
- in the age that differs from the age of the case by not more than 3 years;
- residing in the same oblast as the case.

An additional criterion of matching of controls to cases is applied in the analysis for EWs of 1986-1987, namely, the controls as well as the cases should work in the zone in 1986-1987.

Estimates of the relative risk were obtained using the conditional logistic regression, based on a model in which the relative risk (RR) was assumed to be of the form $exp(\beta Z)$, where Z is the risk factor and β is the regression coefficient. The 95% CI for the RR were calculated as $exp(\beta \pm z_\alpha s_\beta)$, where z_α is the appropriate normal diviate for the two-sided interval and s_β is the asymptotic standard error for the estimated coefficient. Tests of null hypothesis were obtained from the likelihood ratio test statistic. The lack of the effect of the studied factor on the risk was assumed as the null hypothesis. Relative risk assessments and tests for null hypothesis were carried out using the statistical package EGRET [8].

Calculations of SIR with 95% and 99% CI were made as described by P.Boyle and D.M.Parkin [9]. In calculations of SIR external comparisons were made using medical and demographic data for the general male population of the RF.

Results

The basic characteristics of the population under study are shown in Figures 1-9. The mean age of all the EWs as of December 31, 1993 is 40.7, the EWs of 1986-1987 - 40.8. It should be noted that the age distributions of all EWs and EWs of 1986-1987 in percentages of age groups are similar (Figure 1).

External irradiation doses for 80.5% of the EWs covered by the study (for the EWs of 1986-1987 - 78.8%) are available in the RNMDR. For the rest of the EWs doses are unknown. The dose distributions for EWs of all years of entry and EWs of 1986-1987 are different (Figure 2). Almost all doses above 50 mGy refer to the EWs of 1986-1987, whereas in the dose range up to 50 mGy the portion of the EWs of 1986-1987 is less than 50%. The mean dose of external irradiation for EWs of 1986-1987 is higher than for all EWs, 123 mGy and 105 mGy accordingly.

All EWs worked in the zone in different periods of time. Almost 86% of them worked in the zone for one month and over (83.9% of the EWs of 1986-1987). The mean duration of work in the zone for EWs is 2.7 months. This slightly exceeds this index for the EWs of 1986-1987 - 2.5 months. It should also be stressed that almost all EWs stayed in the zone not more than half of a year, namely, all the EWs - 97.3%, the EWs of 1986-1987 - 97.4% (Figure 3).

126,639 emergency workers, or over 81% of the total number of the EWs included in the study, were involved in cleaning operations in 1986-1987 (Figures 4, 5). The peak of their arrival in the zone falls in 1986, and the peak of their departure is 1987. Figures 6, 7 show that the number of EWs arrived and left the Chernobyl zone in 1986-1987[8] is increasing in selected splitting up of time passed after the accident. Dynamics of the rate[9] of entry into the zone dif-

[7] Hereinafter we use the following abbreviations: emergency workers with diagnosis of leukemia - cases; emergency workers selected as control ones - controls.

[8] EWs entered the Chernobyl zone in 1986-1987 and left it in 1988 and later were not considered in construction of diagrams 6-9. Such EWs constitute 4.6% of the total number of EWs of 1986-1987.

[9] Rate of entry (exit) is a ratio of the number of those who entered the Chernobyl zone (left the Chernobyl zone) for a certain period of time to the magnitude of this period. It is measured in persons/day.

fers from dynamics of the intensity of exit from the zone in the same time intervals (Figures 8, 9). The rate of entry of EWs of 1986-1987 declines, the rate of their departure reaches its peak in the second half of 1986.

For the period since 1986 until 1993 48 cases of leukemia were identified among EWs, 41 of them are EWs of 1986-1987. The number of new leukemia cases among EWs increases slightly towards 1991-1993 (Figure 10). 28 cases were occurred for 1991-1993, 23 of them fall on EWs of 1986-1987. As of December 31, 1993 the mean age of all cases was 43, for the cases entered the zone in 1986-1987 - 44.1. This is somewhat higher than corresponding the mean ages for the whole studied population of EWs. Besides, the age distribution of cases is similar to the age distribution of all EWs (Figures 1, 11).

Tables 1-8 present the distributions of cases and controls classified by the risk factors studied. Let us discuss separately these characteristics, first, for cases of all dates of entry in the zone and matched to them controls, and then - for cases entered the zone in 1986-1987 and their controls.

All cases. The percentage of unknown doses for cases is higher than for controls (22.9% and 8.3% accordingly), while the portion of cases from the range 150-199 mGy is more than twice as less than the portion of controls in the same dose range (Table 1). That is why, if in the dose distribution for cases there are two peaks (the first - in dose up to 50 mGy, the second - in 200-249 mGy), then the dose distribution for controls is skewed, i.e. it gradually decreases from the dose range below 50 mGy to doses of 250 mGy and over. The mean dose of external irradiation for controls is 109 mGy, it is slightly higher than the one for cases - 103 mGy. The peak of entry in the Chernobyl zone for cases falls on 1986, while among controls the number of those who entered the zone in 1986 and 1987 is almost the same (Table 2). It should be also noted that on the average cases entered the zone 3 weeks earlier than controls. The number of those left the Chernobyl zone among cases decreases gradually year after year, beginning in 1986 until 1990 and further, while for controls there is the peak of exit which falls on 1987 (Table 3). The distributions of cases and controls by duration of their stay in the zone is similar (Table 4). However, it should be mentioned, that cases on the average stayed in the zone longer than controls - 107 and 90 days accordingly.

Cases of 1986-1987. 22% cases do not have dose records, while only for 7.9% controls doses are unknown (Table 5). In the dose distributions for cases and controls one may note two peaks in 50-99 mGy and 200-249 mGy for cases, and one the pronounced peak in 50-99 mGy for controls. The mean dose for controls is higher than for cases, 134 mGy and 115 mGy accordingly. The percentage of those who entered the zone within the period from 1.01.87 until 30.06.87 is substantially less for cases (12.2%), than for controls (23.8%). Besides, on the average cases entered the zone 20 days earlier than controls (Table 6). As shown in Table 7, there are two the pronounced peaks of exit from the zone for cases, namely, the periods from 1.07.86 until 30.09.86 and from 1.07.87 until 31.12.87. There are two peaks for controls as well. But if the last one is from 1.07.87 until 31.12.87 as for cases, the first falls on the period from 1.10.86 until 31.12.86, and, moreover, these peaks are less clearly defined between each other (a small “ saddle”), than the peaks of exit for cases. On the average cases left the zone a week earlier than controls. It should be noted that out of 9 cases entered the zone before the end of June 1986 only 2 EWs left the zone at the same period. For cases the peak in the distribution by duration of stay in the Chernobyl zone falls on the period from one to two months, and for controls this peak is the interval from one to three months (Table 8). Cases stayed in the zone two weeks more than controls, on the average.

Calculations of SIR showed the significant increase in the incidence of leukemia both among all EWs (SIR: 205, 99% CI: 105-305) and EWs of 1986-1987 (SIR: 200, 95% CI: 118-282) compared to the general male population of Russia in 1991-1993 (Table 9).

Tables 10, 11 present results of estimates of the relative risk of leukemia among EWs. No significant association between leukemia risks and the investigated factors both for all EWs and EWs of 1986-1987 was found.

Discussion

As results of epidemiological studies mainly conducted among atomic bomb survivors in Hiroshima and Nagasaki indicate there is the significantly increased leukemia risk in the exposed populations [10-12]. In atomic bomb survivors, the leukemia incidence began to increase about 2 years after exposure of ionizing radiation in both cites. The increase in the leukemia incidence was statistically significant in the survivors, as compared with the nonexposed population, since 1950, or approximately 5 years after the bombings [13]. As the result of the following studies conducted in a specially created cohort of atomic bomb survivors (Life Span Study) significant estimates of leukemia risks associated with external exposure to low-linear energy transfer ionizing radiation are obtained [14].

The analysis of the RNMDR data presented in the article covers leukemia cases among EWs for almost eight years after the Chernobyl accident. This pe-

riod of time is quite enough for radiation-induced leukemias to arise in the population of EWs. As opposed to the Japanese studies, where estimates of radiation risks were obtained for the cohort exposed to primarily high radiation doses (above 1 Gy) and with follow-up of several million person-years, in our researches EWs received low radiation doses (the mean dose is 105 mGy) and follow-up of EWs is less than a million person-years. That is not enough to find statistically significant estimates of the leukemia risk associated with external irradiation dose among EWs using cohort methods of study. Currently we have not succeeded in finding an association between the leukemia risk and selected factors using the case-control method as well, primarily due to the small number of the cases among EWs. The significant increase in the leukemia incidence among EWs compared to the general male population of the RF is not sufficient evidence that this increase is stipulated only by radiation exposure to EWs. There are other differences except the dose factor between the compared populations and which could influence to such discordance. For example, different medical screening of the populations. More frequent and in-depth medical follow-up of EWs could contributes to better leukemia detection [15]. Therefore in future studies, wherever possible, a stress should be given directly to the dose assessment of the leukemia risk among EWs on the basis of internal comparisons (cohort, either case-cohort, or case-control studies), which are the most precise methods to prove existence of radiation-induced leukemia risks in exposed populations.

When discussing results of the analysis one cannot preclude the possibility that not all leukemia cases in the population of EWs were covered by the study: some of them may be not registered at the present time because of the current system of survey and registration in the RNMDR, the another part of leukemia cases has not been yet verified due to different reasons. Possibly, in the future, all these leukemia cases or a part of them after their registration or verification will add to the total number of currently considered leukemia cases.

The date of the first visit to the physician because of the disease is to be taken as the more correct date of diagnosis in epidemiological studies [1]. However, some cases included in the study do not meet this criterion. For example, in these cases, date of death, date of last blood slide, etc., were taken for these cases as the dates of diagnoses. This was because only these data were available for us from medical documents presented for the verification. Since the process of verification of leukemia diagnoses is constanting being conducted in the RNMDR, clarifications of dates of diagnoses are quite possible in the future.

Work on verification of external irradiation doses received by the EWs during their stay in the Chernobyl zone are going on in the RNMDR. Since this work is not over, one should not exclude a possibility of future modifications and corrections of existing doses, used in the analysis, and thus, obtaining of new risk estimates. However, first results of works on verification of doses for EWs show that there are no large groups of obviously unreliable dosimetric data in the RNMDR [6].

Certainly, in future analyses with the sufficient number of leukemia cases it is necessary to consider the different association with radiation for different leukemia subtypes, as well as a latent period of radiation-induced leukemias (at least 2 years).

Conclusion

EWs constitute a group subjected to the highest radiation risk. Therefore this group is especially important to investigate the long-term health effects in populations exposed to radiation, the low-dose effects in particular. Since it is one of the earliest and most pronounced radiation health consequences, leukemia deserves primary attention in epidemiological studies among EWs. Though the significant increase in the leukemia incidence is seen among EWs compared to the general male population of Russia in 1991-1993, at present it is impossible to evaluate radiation dose-response relationships for leukemia among EWs exactly and with full certainty. Further studies are necessary, which will be able to more closely reflect the situation in the leukemia incidence among EWs on the basis of new data, and, probably, will lead to more important and meaningful results in assessments of radiation risks of leukemia.

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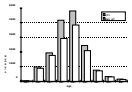


Figure 1. Distribution of EWs by age at 31 December 1993.

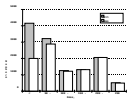


Figure 2. Distribution of EWs by external irradiation dose.

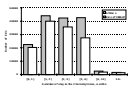


Figure 3. Distribution of EWs by duration of stay in the Chernobyl zone.

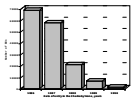


Figure 4. Distribution of EWs by date of entry into the Chernobyl zone.

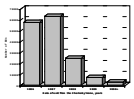


Figure 5. Distribution of EWs by date of exit from the Chernobyl zone.

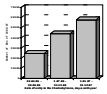
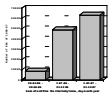
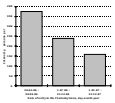


Figure 6. Distribution of EWs of 1986-87 by date of entry into the Chernobyl zone.



Date of exit from the Chernobyl zone, day.month.year

Figure 7. Distribution of EWs of 1986-87 by date of exit from the Chernobyl zone.

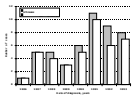


Date of entry from the Chernobyl zone, day.month.year

Figure 8. Intensity of entry in the Chernobyl zone for EWs of 1986-87.

Date of exit from the Chernobyl zone, day.month.year

Figure 9. Intensity of exit from the Chernobyl zone for EWs of 1986-87.



Date of diagnosis, years

Figure 10. Distribution of cases of leukemia among EWs by date of diagnosis.

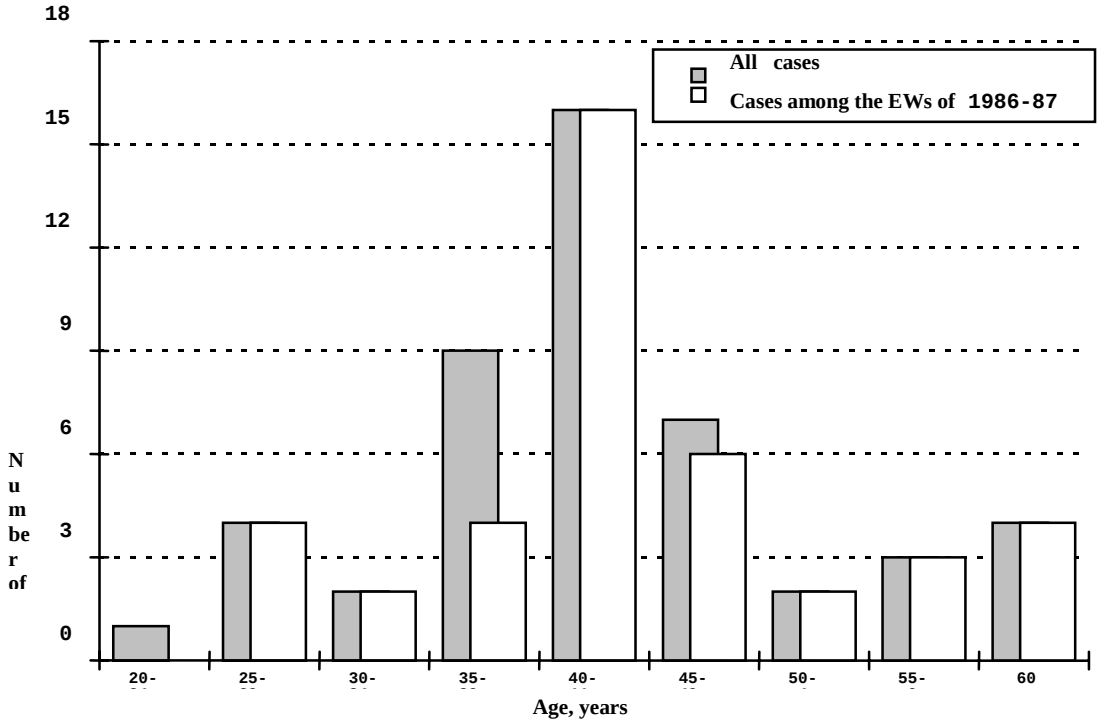


Figure 11. Distribution of cases of leukemia among the EWs by age at 31 December 1993.

Table 1

Distribution of leukemia cases among EWs and controls by external irradiation dose

Dose (mGy)	Cases	Controls	All
Average dose	103	109	108
Range	1 – 250	1 - 251	1 - 251
< 50	12 (25.0%)	48 (25.0%)	60 (25.0%)
50 - 99	8 (16.7%)	41 (21.4%)	49 (20.5%)
100 - 149	6 (12.5%)	27 (14.1%)	33 (13.7%)
150 - 199	3 (6.2%)	27 (14.1%)	30 (12.5%)
200 - 249	7 (14.6%)	26 (13.5%)	33 (13.7%)
250+	1 (2.1%)	7 (3.6%)	8 (3.3%)
No data	11 (22.9%)	16 (8.3%)	27 (11.3%)
Total	48 (100%)	192 (100%)	240 (100%)

Table 2

Distribution of leukemia cases among EWs and controls by date of entry in the Chernobyl zone

Date of entry (year)	Cases	Controls	All
Average date (day/month/year)	07/04/87	28/04/87	24/04/87
Range (day/month/year)	26/04/86-20/12/90	26/04/86-14/12/89	26/04/86-20/12/90
1986	25 (52.1%)	80 (41.7%)	105 (43.8%)
1987	16 (33.3%)	78 (40.6%)	94 (39.2%)
1988	5 (10.4%)	28 (14.6%)	33 (13.7%)
1989	1 (2.1%)	6 (3.1%)	7 (2.9%)
1990	1 (2.1%)	0 (0.0%)	1 (0.4%)
Total	48 (100%)	192 (100%)	240 (100%)

Table 3

Distribution of leukemia cases among EWs and controls by date of exit from the Chernobyl zone

Date of exit (year)	Cases	Controls	All
Average date (day/month/year)	23/07/87	27/07/87	27/07/87
Range (day/month/year)	30/05/86-03/03/92	30/04/86-14/03/91	30/04/86-03/03/92
1986	19 (39.6%)	68 (35.4%)	87 (36.2%)
1987	17 (35.4%)	78 (40.6%)	95 (39.6%)
1988	9 (18.7%)	35 (18.2%)	44 (18.3%)
1989	2 (4.2%)	8 (4.2%)	10 (4.2%)
1990+	1 (2.1%)	3 (1.6%)	4 (1.7%)
Total	48 (100%)	192 (100%)	240 (100%)

Table 4

Distribution of leukemia cases among EWs and controls by duration of stay in the Chernobyl zone

Duration of stay (months)	Cases	Controls	All
Average duration (days)	107	90	93
Range (days)	7 - 1004	2 - 1783	2 - 1783
< 1	9 (18.8%)	28 (14.6%)	37 (15.4%)
1 - < 2	12 (25.0%)	54 (28.1%)	66 (27.5%)
2 - < 3	12 (25.0%)	53 (27.6%)	65 (27.1%)
3 - < 6	10 (20.8%)	51 (26.6%)	61 (25.4%)
6 - < 12	2 (4.2%)	1 (0.5%)	3 (1.3%)
12+	3 (6.2%)	5 (2.6%)	8 (3.3%)
Total	48 (100%)	192 (100%)	240 (100%)

Table 5

Distribution of leukemia cases among EWs of 1986-87 and controls by external irradiation dose

Dose, (mGy)	Cases	Controls	All
Average dose	115	134	130
Range	1 - 250	1 - 500	1 - 500
< 50	7 (17.1%)	22 (13.4%)	29 (14.1%)
50 - 99	8 (19.5%)	36 (22.0%)	45 (21.9%)
100 - 149	6 (14.6%)	26 (15.8%)	32 (15.6%)
150 - 199	3 (7.3%)	29 (17.7%)	32 (15.6%)
200 - 249	7 (17.1%)	29 (17.7%)	36 (17.6%)
250+	1 (2.4%)	9 (5.5%)	10 (4.9%)
No data	9 (22.0%)	13 (7.9%)	22 (10.7%)
Total	41 (100%)	164 (100%)	205 (100%)

Table 6

Distribution of leukemia cases among EWs of 1986-87 and controls by date of entry in the Chernobyl zone

Date of entry	Cases	Controls	All
Average date (day/month/year)	20/12/86	09/01/87	05/01/87
Range (day/month/year)	26/04/86-25/11/87	26/04/86-27/12/87	26/04/86-27/12/87
26 Apr. - 31 May 1986	5 (12.2%)	16 (9.8%)	21 (10.3%)
1 June - 30 June 1986	4 (9.8%)	11 (6.7%)	15 (7.3%)
1 July - 30 Sept. 1986	11 (26.8%)	35 (21.3%)	46 (22.4%)
1 Oct. - 31 Dec. 1986	5 (12.2%)	24 (14.6%)	29 (14.1%)
1 Jan. - 30 June 1987	5 (12.2%)	39 (23.8%)	44 (21.5%)
1 July - 31 Dec. 1987	11 (26.8%)	39 (23.8%)	50 (24.4%)
Total	41 (100%)	164 (100%)	205 (100%)

Table 7

Distribution of leukemia cases among EWs of 1986-87 and controls by date of exit from the Chernobyl zone

Date of entry	Cases	Controls	All
Average date (day/month/year)	01/04/87	08/04/87	06/04/87
Range (day/month/year)	30/05/86-24/01/89	30/04/86-14/03/91	30/04/86-14/03/91
26 Apr. - 31 May 1986	1 (2.4%)	6 (3.7%)	7 (3.4%)
1 June - 30 June 1986	1 (2.4%)	7 (4.3%)	8 (3.9%)
1 July - 30 Sept. 1986	10 (24.4%)	24 (14.6%)	34 (16.6%)
1 Oct. - 31 Dec. 1986	7 (17.1%)	37 (22.5%)	44 (21.5%)
1 Jan. - 30 June 1987	6 (14.6%)	32 (19.5%)	38 (18.5%)
1 July - 31 Dec. 1987	11 (26.8%)	47 (28.7%)	58 (28.3%)
1 Jan. 1988+	5 (12.2%)	11 (6.7%)	16 (7.8%)
Total	41 (100%)	164 (100%)	205 (100%)

Table 8

Distribution of leukemia cases among EWs of 1986-87 and controls by duration of stay in the Chernobyl zone

Duration of stay (months)	Cases	Controls	All
Average duration (days)	102	88	91
Range (days)	7 - 1004	2 - 1783	2 - 1783
< 1	9 (22.0%)	30 (18.3%)	39 (19.0%)
1 - < 2	11 (26.8%)	48 (29.3%)	59 (28.8%)
2 - < 3	9 (22.0%)	48 (29.3%)	57 (27.8%)
3 - < 6	8 (19.4%)	32 (19.5%)	40 (19.5%)
6 - < 12	2 (4.9%)	1 (0.6%)	3 (1.5%)
12+	2 (4.9%)	5 (3.0%)	7 (3.4%)
Total	41 (100%)	164 (100%)	205 (100%)

Table 9

Observed (O) and expected (E) numbers of leukemia cases among EWs, standardized incidence ratio (SIR) with 95% and 99% confidence intervals (CI) in 1991-1993

	O	E	SIR	95% CI	99% CI
All EWs	28	13.6	205	129 - 281	105 - 305
EWs of 1986-87	23	11.5	200	118 - 282	92 - 308

Table 10

Relative risk (RR), 95% confidence interval (CI) and χ^2 test statistic for leukemia among EWs by date of entry in the Chernobyl zone, date of exit from the Chernobyl zone, duration of stay in the Chernobyl zone, external irradiation dose

Baseline risk factor level	Risk factor categories	χ^2	Degrees of freedom	p	RR (odds ratio)	95% CI
Date of entry in the Chernobyl zone (years)						
1987 - 1990	1986	2.26	1	0.13	1.75	0.85 - 3.61
1988 - 1990	1987	2.27	2	0.32	0.96	0.35 - 2.64
	1986				1.71	0.64 - 4.58
Date of exit from the Chernobyl zone (years)						
1987+	1986	0.48	1	0.49	1.35	0.58 - 3.11
1988+	1987	0.69	2	0.71	0.81	0.34 - 1.93
	1986				1.19	0.45 - 3.15
Duration of stay in the Chernobyl zone (months)						
< 3	3+	0.05	1	0.82	1.09	0.52 - 2.28
< 1	1 - < 2	0.84	3	0.84	0.63	0.21 - 1.86
	2 - < 3				0.63	0.21 - 1.93
	3+				0.74	0.24 - 2.26
Dose (mGy)						
< 200	200+	0.16	1	0.69	1.22	0.47 - 3.18
< 100	100-199	0.34	2	0.85	0.82	0.33 - 2.05
	200+				1.14	0.42 - 3.12

Table 11

Relative risk (RR), 95% confidence interval (CI) and χ^2 test statistic for leukemia among EWs of 1986-87 by date of entry in the Chernobyl zone, date of exit from the Chernobyl zone, duration of stay in the Chernobyl zone, external irradiation dose

Baseline risk factor level	Risk factor categories	χ^2	Degrees of freedom	p	RR (odds ratio)	95% CI
Date of entry in the Chernobyl zone (years)						
1.01.87 - 31.12.87	1.07.86 - 31.12.86	1.89	2	0.39	1.48	0.63 - 3.49
	26.04.86 - 30.06.86				2.27	0.68 - 7.57
1.07.87 - 31.12.87	1.01.87 - 30.06.87	4.93	4	0.30	0.39	0.11 - 1.32
	1.10.86 - 31.12.86				0.87	0.27 - 2.79
	1.07.86 - 30.09.86				1.35	0.49 - 3.70
	26.04.86 - 30.06.86				1.67	0.48 - 5.81
Date of exit from the Chernobyl zone (years)						
1.10.86+	26.04.86 - 30.09.86	1.19	1	0.28	1.71	0.65 - 4.49
1.07.87+	1.01.87 - 30.06.87	1.88	3	0.60	0.67	0.24 - 1.86
	1.10.86 - 31.12.86				0.77	0.26 - 2.26
	26.04.86 - 30.09.86				1.43	0.46 - 4.46
Duration of stay in the Chernobyl zone (months)						
< 3	3+	0.81	1	0.37	1.50	0.63 - 3.56
< 1	1 - < 2	1.60	3	0.66	0.72	0.24 - 2.17
	2 - < 3				0.58	0.18 - 1.91
	3+				1.02	0.30 - 3.52
Dose (mGy)						
< 200	200+	0.01	1	0.92	1.05	0.40 - 2.76
< 100	100 - 199	0.63	2	0.73	0.69	0.28 - 1.73
	200+				0.89	0.31 - 2.53