Increase of Regional Total Cancer Incidence in North Sweden Due to the Chernobyl Accident?

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Abstract
Study objective. Is an increase of cancer incidence detectable in Sweden due the Chernobyl accident?
Design. The fallout of caesium-137 was studied in relation to the cancer incidence 1988-1996.
Setting. In Northern Sweden, affected by the Chernobyl accident in 1986, we categorised 450 parishes by caesium-137 deposition: <3 (reference), 3-29, 30-39, 40-59, 60-79 and 80-120 kBq/m^2.
Participants. All individuals 0-60 years of age and living in these parishes in 1986 were included i.e. 1 143 182 persons. In the follow-up 22 409 cancer cases were recorded in 1988-1996.
Main results. Controlling for age and various other factors, potentially to influence the result, the adjusted relative risks for the exposure categories were 1.00 (reference <3 kBq/m^2), 1.05, 1.03, 1.08, 1.10 and 1.21. The excess relative risk was 0.11 per 100 kBq/m^2 (95% CI 0.03;0.20). The cancer incidence rate differences between 1988-1996 and the reference period 1986-1987 in each category were 30.3, 36.8, 42.0,

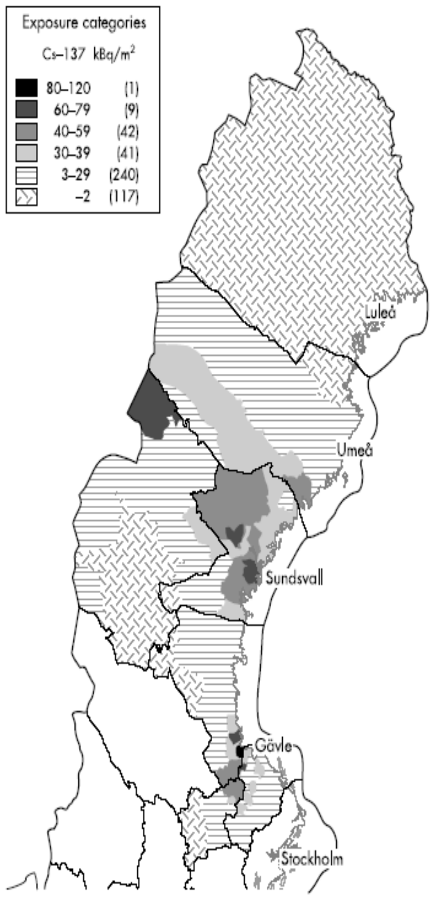

Figure 1. Parishes in the study area classified by ground deposition of caesium-137 and number of parishes in parentheses for each category. The map was originally produced by the Geological Survey of Sweden on behalf of the Swedish Radiation Protection Authority, here modified after permission from the latter.

45.8, 50.1 and 56.4 per 100 000 persons. No clear excess occurred for leukaemia or thyroid cancer.
Conclusions. A slight exposure-related increase in total cancer incidence has occurred in Northern Sweden after the Chernobyl accident.

Introduction

In Europe concerns about the consequences of the Chernobyl accident have focused on childhood malignancies, especially leukaemia, assumed to have a short latency period after irradiation. Several studies have been performed outside the former Soviet Union, but none has shown any clear relationship with the fallout from the Chernobyl accident. However, children exposed during pregnancy have shown an increased risk of leukaemia in Greece, Germany and Ukraine, but not in Belarus. A recent study from Ukraine reports an increase in adult leukaemia after exposure from Chernobyl radiation. In Belarus, Ukraine and the western part of Russia, there has been a dramatic increase in thyroid cancer incidence in children related to the accident. In other parts of Europe a similar increase in thyroid cancer has been seen in adults.

Five percent of the released caesium-137 from the Chernobyl accident was deposited in Sweden due to heavy rainfall on 28-29 April 1986, mainly in the eastern coastal regions from Umeå in the North to Stockholm in the South. During the first weeks the main contributors to the radiation dose were short-lived nuclides replaced by long-lived caesium-134 and caesium-137 isotopes. The dose to the inhabitants, depending on place of residence, outdoor activity and dietary habits, ranged from 1-2 mSv to a maximum of about 4 mSv the first year.

Our investigation includes the population of seven counties with the highest fallout, all in Northern Sweden. There were also unaffected areas in these counties serving as internal reference areas. The South of Sweden was excluded as much less affected by the fallout, but also because of higher background cancer incidence rates, especially in the largest cities.

Methods

Out of Sweden's 21 counties, the seven counties included in this study were Norrbotten, Västerbotten, Jämtland, Västernorrland, Gävleborg, Västmanland and Uppsala County. These counties and some major cities are shown in Figure 1. All individuals in the population registry who were 0-60 years old in 1986 and who had the same address both on 31 December 1985 and 31 December 1987 were included in the study. Cancer cases and deaths along with date of diagnosis were retrieved from the Swedish Cancer Registry for 1986 to 1996. The follow-up period started on January 1, 1988 including 1 143 182 persons with information on age, sex and parish of residence during the two preceding years. Number of cancer cases during the follow-up 1988-1996 are given in Table 1.

By assignment with the Swedish Radiation Protection Authority, the Geological Survey of Sweden had performed aerial gamma-measurements over the entire Sweden from May to October 1986 resulting in a ground deposition map of caesium-137 in 12 different categories. Collapsing these categories, the population in the 450 parishes, i.e., the smallest administrative units of these seven counties, were classified into six exposure categories: <3, 3-29, 30-39, 40-59, 60-79 and 80-120 kBq/m^2 (Figure 1 and Table 1). The 117 parishes not affected (<3 kBq/m^2) in these counties served as reference areas.

The relative risks were adjusted by population density, smoking habits, socio-economic factors and cancer incidence in the parishes before the accident (1986-1987). The risk difference was calculated as the age adjusted cancer incidence during the follow-up (1988-1996) minus the cancer incidence in each exposure category before the Chernobyl accident (1986-1987). Hence, the relative comparison in incidence is within the column and the difference is a horizontal comparison of incidence before and after the Chernobyl accident.

Table 1. Number of individuals and cancer cases by exposure category. Adjusted relative risks by category in relation to the unexposed (reference category). Age standardised risk difference as incidence per 100 000 persons during the follow-up period 1988-1996, minus the incidence 1986-1987 for each exposure category, respectively. Statistical uncertainty expressed as confidence interval (95% CI) i.e. a relative risk above 1.00 and a risk difference above 0.00 is statistical significant, respectively.

Exposure kBq Cs-137/m^2	Population 1 January 1988	Number of cancer cases 1988-1996	Relative risk (95 % CI)	Risk difference (95% CI)
<3	359 509	6 691	1.00 (reference)	30.3 (25.5-35.2)
3-29	527 812	10 378	1.05 (0.99-1.11)	36.8 (32.6-41.0)
30-39	92 323	1 827	1.03 (0.95-1.12)	42.0 (33.0-51.0)
40-59	124 862	2 744	1.08 (0.94-1.23)	45.8 (37.9-53.4)
60-79	21 625	401	1.10 (0.89-1.34)	50.1 (29.4-70.8)
80-120	17 051	368	1.21 (0.98-1.49)	56.4 (33.9-78.9)
Total number	1 143 182	22 409		

Results

The relative risk for all cancer sites showed a slight increase in all exposure categories using <3 kBq caesium-137/m^2 as the internal reference. As an average over the categories an excess relative risk of 0.11 (95% CI 0.03-0.20) per 100 kBq/m^2 was calculated. Because of an ageing population it was necessary to restrict the population to 5-59 years of age in order to obtain the risk difference corresponding to 13 823 cancer cases for the follow-up period. The risk difference of 30.3 per 100 000 persons in the reference category represents the underlying time trend i.e. the increase in cancer incidence not affected by the Chernobyl fallout (Table 1). Neither the relative risks, nor the risk differences could be explained by different smoking habits in the exposure categories. Radiosensitive neoplasms with assumed short latencies like leukaemia and thyroid cancer did not increase in relation to the radioactive fallout in North Sweden after the Chernobyl accident.

Discussion

Before the study we realized that if there would be a effect on the cancer incidence due to the Chernobyl accident it would only be a small such risk. Therefore we designed our study to be as sensitive as possible to catch such an increase, if existing. As many exposed counties as possible were included, small geographical areas (parishes) were used for assessing the exposure, we used a two year residence inclusion criteria as a considerable part of the dose from the Chernobyl accident was achieved during that time and finally we applied an age restriction i.e. an age span with expected low incidence of malignancies in general. A better exposure assessment would have been obtained if we could have traced the addresses of each individual during the follow-up period. However, most likely the majority of the population has continued to live in the same parish throughout the duration of the study.

Unless simply representing a chance phenomenon, the findings in our study are somewhat unexpected indicating a possible cancer effect of the Chernobyl fallout in North Sweden despite a short latency period and low degree of exposure. This is the first study suggesting a possible increase in total cancer incidence after the Chernobyl accident outside the former Soviet Union, let alone only a marginally increased risk. Out of the 22 409 cancer cases an estimated 849 cases could be attributed to the fallout from the Chernobyl accident. However, no less than 494 of these cases are derived from the second category 3-29 kBq/m^2. A slightly different classification of the reference categories would therefore dramatically influence the number of exposure-related cancer cases.

Using the estimated collective dose in Sweden of about 6 000 man-Sv during 50 years due to Chernobyl contamination, and the risk estimates given by the International Commission on Radiological Protection, the number of expected extra cancer deaths could be calculated to 300. Given a true effect, our study indicates that the risk from low dose irradiation might come earlier and be slightly higher than predicted by the International Commission on Radiological Protection estimates. The official risk estimate relies to a great extent on the follow-up of the atomic bomb survivors in Hiroshima and Nagasaki, but has been questioned because only those alive in 1950 were included in the study, hence ignoring early cancer cases.

A short latency period like in our study has been seen in other epidemiological studies on ionising radiation. Our findings of an increase of total cancer incidence in Sweden soon after the Chernobyl accident is therefore not a unique finding, but we have not been able to detect any specific cancer site responsible for our findings. An interpretation could therefore be that the ionising radiation might exert a late stage general promoting effect on cancer.

A larger problem is that the exposure assessment was based on the ground deposition of caesium-137 from the Chernobyl accident, not taking into account any internal dose contribution through food and inhalation. This is especially important in regions with relatively low ground deposition where a high intake of wild berries, mushrooms, game meat et cetera would give a higher internal than external dose from caesium-137. Restrictions in food intake due to governmental regulation are likely to have led to lower doses, especially in higher exposed areas, hence lowered the radiation-induced cancer risks for the population in comparison to what would otherwise have prevailed. Such information on an individual level is practical is impossible in a large population as in our study.

We could not find an association between the radiation from the Chernobyl accident on thyroid cancer. Regarding the thyroid cancer the iodine status of the Swedish population is good in contrast to children in the former Soviet Union where a dramatic increase has been seen. This is probably making the Swedish population less sensitive in addition to that locally produced food plays a limited role in the areas with high fallout in Sweden. It is also possible that the radiation levels were too low in Sweden to cause an increased risk of thyroid cancer.

We were also unable to detect any clear increase in leukaemia during the follow-up in relation to the radiation from the Chernobyl accident. Similarly, not even in the most heavily polluted areas in the former Soviet Union any clear increase of leukaemia has been observed as yet, except a recent report from Ukraine. On the other hand, it has been suggested that the established association between ionising radiation and leukaemia is unique for the relatively high, but short exposure to radiation after the atomic bomb explosions and maybe not applicable in low dose studies.

The follow-up period is still rather short in our study and a longer study period is necessary for any more definitive conclusions about a causal relationship between the radioactive fallout in Sweden and the cancer incidence. Should we be observing some late stage promotion effect on ongoing cancer development in the population, there might even follow a decrease in the cancer incidence with an about normal cumulative incidence over a longer period of time. This remark, however, is a speculative conjecture to be addressed in future studies.

Reference

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