

Cancer, epidemiology and nuclear accidents

2016 marks the 30th and 5th anniversaries of the accidents at the Chernobyl and Fukushima nuclear power plants respectively. Both incidents had a considerable environmental impact, and large population groups were exposed to elevated doses of radiation.

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After the Chernobyl disaster in Ukraine, the mass media made dismal predictions of elevated risks of cancer. Today, we can start to draw conclusions regarding whether these have been borne out, which may help us make some prognoses for the after-effects of the Fukushima accident in Japan.

Survivors of the nuclear bombings of Hiroshima and Nagasaki in Japan are our most important evidence base on the association between radiation exposure and cancer. The Life Span Study has followed 120 000 survivors of the nuclear blasts, as well a control group of 26 000 people who lived in the cities in question, but were absent when the bombs detonated, from 1950 until today (1). In those who were exposed to radiation, increased prevalence of a number of cancers has been established when compared to the control group.

Leukaemia and solid tumours

Not many years after the nuclear explosions a rapid increase in the incidence of leukaemia and other haematological malignancies was established. The increase in new cases of leukaemia was highest in the youngest age groups. For the group as a whole, it has been estimated that in the period 1950–1955, the risk of leukaemia among survivors of the nuclear bombings after a radiation dose of 1 Gy exceeded that of the control group by a factor of 15 (excess relative risk, ERR = 15.2). The ERR gradually declined, but for the period 1990–2001 it was still estimated that the group that had been exposed to radiation had twice the risk of haematological malignancies (ERR = 2.1) per Gy (2).

Some years after the first increase in cases of acute leukaemia, an incipient increase in the incidence of numerous types of solid cancers was detected, especially cancer of the breast, lungs and gastrointestinal tract. The incidence of these types of cancer has continued to increase at a steady

rate. The risk of a solid tumour after radiation is influenced by age, gender, the type of neoplasm, radiation dose and the time that has elapsed since the nuclear explosions. It has been estimated that a person who was 30 years old when the atom bombs exploded will have a 35 % elevated risk of a solid tumour per Gy of radiation exposure 40 years later, when all types of cancer are seen as a whole (ERR = 0.35) (3). The Life Span Study, as well as results from examinations of patients who have been exposed to radiation for diagnostic or treatment purposes in a medical context (4, 5), show that there is a direct association between radiation and cancer. Data from these studies have later been used to prepare mathematical models for prognostication of the number of potential new cases of cancer after accidents involving radiation.

Chernobyl

Human error, combined with a construction flaw in the reactor, caused the cooling system of the Chernobyl reactor to malfunction on the night of 25 April 1986. This caused an explosion in the reactor core, whereby radioactive material, including radioactive iodine and caesium, was hurled into the air. The explosion was followed by a fire that lasted for ten days. Most of the radioactive material fell over the adjacent areas in northern Ukraine, Belarus and western Russia, while some was sucked into higher layers of the atmosphere and carried by the wind to distant European countries such as Germany, France, Norway and Sweden (6). The Chernobyl accident is the largest nuclear incident ever to happen in peacetime.

Cancer of the thyroid gland

No more than a few years after the accident, hospitals in Belarus reported a considerable increase in the number of cases of thyroid cancer in children (7). Gradually, similar reports started to emerge from Ukraine and Russia. It was determined that this increase was directly linked to radioactive iodine exposure, and it was greatest among very young children. The incidence of new cases of thyroid cancer gradually increased over

the next decade, after which it appears to have remained stable at the same level until today. Different reports state the ERR to range from 19.0 to 4.5 per Gy, depending on the children's age. Iodine deficiency in the population, combined with intake of milk contaminated by radioactive iodine, has contributed to the increased incidence of thyroid cancer (8). Fortunately, the vast majority of the patients have responded well to treatment. A UN report from 2006 notes that until then, approximately 4000 new cases of thyroid cancer had been detected in children in Belarus, Russia and Ukraine in the time after the Chernobyl accident, but only 15 deaths had been recorded among these cases (9).

Epidemiological studies and prognostic models

Estimates of cancer incidence after nuclear accidents can be grouped into two main types: The first type is a prognostic estimate based on previous experience of cancer incidence in other groups who have been exposed to radiation. The second type consists of epidemiological studies of selected population groups.

With the aid of a prognostic model specially adapted to exposure to low doses of radiation over an extended period, it has been estimated that in all the countries involved approximately 40 000 cases of cancer will occur over a period of 100 years as a result of the Chernobyl accident. Half of these will be thyroid cancers, and it has been estimated that the number of new cases in Ukraine, Belarus and Russia will be equal to the number in all the other European countries combined. However, these 40 000 cases will account for no more than 0.01 % of the total number of cancer cases anticipated during this period (10).

After Chernobyl

Epidemiological studies undertaken after the Chernobyl accident have concentrated on the workers who cleaned up the accident site, the so-called «liquidators». Altogether 600 000 people were exposed to substantial doses of radiation during this work. Two major international case-control studies have been published, both of which con-



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clude that this group has an elevated prevalence of haematological malignancies (11, 12). Although patient selection was a factor in both studies, the conclusions carry weight because the studies comply with other quality standards, such as individual documentation of radiation doses and quality assurance of each patient's diagnosis provided by an international panel of experts. Moreover, two large-scale Russian studies have been published, with the conclusion that an excess frequency of haematological malignancies as well as solid tumours among the clean-up workers was evident when compared to the general population (13, 14). However, methodological issues render an assessment of these studies uncertain. Underdiagnosis and underregistration of cancers in the general population in the countries concerned, combined with the introduction of special screening programmes for diagnosis and registration of cancer among the clean-up workers, may have been the reason for the increased rate of cancer registered in this group (screening effect).

No measurable increase in cancer incidence after the Fukushima accident

The earthquake on 11 March 2011 caused a tsunami that struck the Fukushima nuclear power plant. The power plant is located near the sea and was protected against waves up to 13 metres in height, but on that day the waves exceeded this level. At the time of the accident, three of the reactors were in operation. The flooding caused the cooling system to malfunction, and the temperature inside the reactors rose gradually. Parts of the protective mantle around the fuel rods melted, and hydrogen gas leaked out. This caused a chemical explosion that damaged the reactor buildings, but the reactors themselves remained intact. To prevent pressure from building up and causing an explosion, the reactors were opened for venting in several rounds, and radioactive gases were thus released into the environment. The emissions of radioactive material from the Fukushima power plant amounted to approximately one-tenth of the emissions caused by the Chernobyl accident. More-

over, 80 % of these emissions were carried out to sea by the wind. The radioactive fallout over land was thus on a considerably smaller scale than that from Chernobyl and primarily located in the region around the power plant (15).

No increased incidence of thyroid cancer in children has so far been registered since the Fukushima accident. Probable contributory factors are that children in this area do not suffer from iodine deficiency and that the distribution of local dairy products was halted immediately (16). A prognosis of cancer risk shows that radioactive pollution after the Fukushima accident may cause 730–1700 new cancer cases, i.e. somewhat more than one per cent of the Chernobyl accident (17). Approximately 20 000 workers participated in the clean-up after the accident, but only 39 of them were exposed to radiation doses exceeding 0.1 Sv. It has been estimated that of these, approximately 12 cases of cancer will occur as a result of the radiation (18). It will be impossible to verify this estimated minimal increase in cancer after Fukushima with the aid of epidemiological studies.

A moderate cancer risk after the Chernobyl accident

To date, an increase in thyroid cancer in children after the Chernobyl accident is the only association between cancer and radiation exposure after a nuclear accident to be established with certainty. In addition, a likely increase in the incidence of haematological malignancies has been established among the clean-up workers in Chernobyl. Even though epidemiological studies of cancer risk after accidents in nuclear power plants are fraught with methodological problems, available studies indicate that the increase in cancer risk resulting from the Chernobyl accident was moderate. In other words, the most dismal predictions propounded in this respect by the mass media after the accident were unfounded.

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