Chernobyl: 10 Years Later

Five years after the accident at Chernobyl occurred on April 26, 1986, there was still significant international disagreement about the short- and long-term health effects. With the occasion of the 10th anniversary of the accident, there have been three recent international conferences on Chernobyl. These have been sponsored by the European Commission (EC), International Atomic Energy Agency (IAEA) and the World Health Organization (WHO). In contrast to the earlier differences of opinion, the international community has now come to a consensus on several issues, some of which are well known and some of which are less well known. This report concentrates on issues that may be of direct interest to nuclear medicine physicians.

Release of Radioactive Materials

The first issue is the estimated release of radioactive materials from the reactor. Estimates have now been revised and the total releases of ^{131}I and ^{137}Cs are substantially greater than those of the June 1986 evaluation. There also has been a significant increase in the estimates of very short-lived radionuclides. Estimates of some radionuclides made in 1988 by the United Nations as well as those presented at the recent WHO/IAEA/EC Vienna conference are shown in Table 1. Most of the long-term whole-body radiation doses are the result of external exposure from cesium activity on the ground and to a lesser extent from the ingestion of cesium in food stuffs. Because most dose estimates were based upon actual measurements of radioactivity on the ground and in food as well as whole-body counts, revision of the source term will not affect calculated doses to the whole body.

Table 1
Estimates of Major Radionuclides Released at Chernobyl

Radionuclide	1988 Estimates UNSCEAR* PBq (MCi)	1996 Estimates PBq (MCi)
^{85}Kr	33 (0.9)	33 (0.9)
^{133}Xe	1700 (63)	6500 (175)
^{131}I	260 (9.6)	1200-1700 (32-46)
^{133}I	not estimated	2500 (68)
^{132}Te	48 (1.8)	1100 (30)
^{134}Cs	19 (0.7)	44-54 (1.2-1.5)
^{137}Cs	38 (1.4)	74-85 (2.0-2.3)
^{90}Sr	8 (0.2)	8-10 (0.2-0.3)

—*Effects and Risks of Ionizing Radiation, United Nations Scientific Effects of Atomic Radiation, 1988 Report to the General Assembly with Annexes, p. 344, Vienna 1988.*

The revision of the emission of short-lived radioiodine estimates may, however, have some bearing on the appearance of thyroid cancer, as discussed below. It is of interest to note that one-third of the estimated committed dose from the accident for all the affected populations was received in the first year after the accident. An additional one-third of the dose has been received in the following nine years and only one-third (or less) has yet to be received. The natural background radiation in the area is about half that of some European countries. It has been estimated that if the relocated population were to return home to contaminated territories outside the 30-km exclusion zone, their annual whole-body doses over the next 60 years, even with the remaining contamination, will be less than that produced by the natural background of some European countries such as Finland and Sweden. The reasons for not returning to many evacuated settlements now largely depends on psychological and social issues as well as the economic costs of moving and the need to rebuild deteriorated infrastructures (such as schools, water supply, etc.).

Mortality of exposed worker populations has been a matter of intense study. There were 143 plant workers and firemen who received doses high enough to cause acute radiation syndrome. Of these, 31 died within three months. Two persons died directly as a result of the explosion and one died of a myocardial infarction. Twenty-eight died from bone marrow suppression and gastrointestinal damage. Many of these also had major complicating beta burns. Bone marrow transplantation was attempted in 13 patients. Eleven of these died from several causes, including immunological problems related to the transplants. Two patients survived the procedure with regeneration of their native marrow, indicating that they had not needed the transplants. Therefore, today bone marrow transplantation is thought not to be beneficial. Future management of patients with severe acute radiation syndrome will likely focus instead on the use of stimulating factors on residual marrow and perhaps transfusions of stem cells. An additional 14 of the 143 acute radiation syndrome patients have died through 1996, although only two of these deaths are thought to be possibly radiation-related.

There is another group of workers called liquidators or clean-up workers. About 200,000 of these persons worked in 1986 and 1987 and received an average whole-body dose of about 0.1 Sv (10 rem). An additional 450,000 workers were at the site in later years but received little exposure. The exact number of these groups who have died from any cause is unknown, at least in part, because they are now dispersed throughout the former USSR. Many of them would be expected to have died to date as a result of non-radiation related causes. The only comparative data is from a registry in Obninsk which reports that, as of the end of 1995, the mortality rate of this "liquidator" group is not significantly different from other populations. This should be considered in the context of an overall decreasing average lifespan for males (now down to 59 years) in the former USSR. This is due, in part, to a marked increase in suicides, homicides, motor vehicle accidents, alcoholism and cardiovascular diseases.

Incidences of Leukemia

Leukemia is considered a sentinel neoplasm after radiation exposure. Increases in leukemia were predicted to occur and were expected to be seen in children 2 to10 years after the accident and in adults from 10 to 30 years postexposure. At the Vienna conference, predictions of total leukemias for all exposed populations (including liquidators, evacuated persons and those still living on contaminated territories) during the first 10 years were estimated to be 2350 cases of which 315 were radiation-induced. Currently, Belarus, Russia and the Ukraine have reported that to date they have not seen any increase in leukemia in children or adults living in contaminated areas. This is in contrast to the press statements or the implications of the pictures of "leukemic" or epilated children (implying chemotherapy) that have appeared in the media.

To date, there may be a nonsignificant increase of leukemia in those emergency workers who received relatively high doses. The reasons for not finding an increase in children are speculative (e.g., an increase was present but very small and could not be detected through the existing medical record system or the fact that the dose was protracted and resulted in an increase even smaller than predicted on the basis of acute exposures).

Increase in Solid Cancers

Data from most other radiation-exposed populations indicates that an increase in solid cancers does not begin until about 10 years after exposure. Thus, an increase in these cancers in the Chernobyl area was not expected at this time, although there have been unconfirmed media reports of an increase in these tumors from contaminated areas. The authorities in Belarus and the Ukraine now report that while there has been an increase in cancer mortality, an identical rate of increase was present before the accident and that no difference in cancer mortality between exposed and nonexposed populations is present to date.

Current predictions are that for all exposed populations there eventually may be an excess of about 6500 radiation-induced cancer cases on a background of about 540,000 spontaneous cases. This increase of just over 1 percent will be difficult to detect, particularly if there is a dose rate reduction effect. It is possible that increases in both leukemia and solid cancers may eventually be seen if careful long-term studies are conducted on the most highly exposed group of emergency workers.

Increase in Thyroid Cancer

A very large increase in the incidence of thyroid cancer in young children has been seen with a surprisingly short latent period. These cases have predominantly appeared in those who were children under four years of age at the time of the accident. They first began to appear in 1990 and have continued to the present. No significant increase has been apparent in adults. In the children, there are currently about 800 reported cases and three reported deaths.

Many of the cases have been reported in the Gomel area of southern Belarus. About 95% of the cases are papillary cancers and about 75% of these are the solid follicular type. Initially, it was suspected that increased screening played a role in the appearance of these tumors. Even though there have been extensive ultrasound screening programs, most patients have presented through traditional routes, either by a parent or by routine school physical examinations (which include thyroid palpation).

The pre-Chernobyl background rates of thyroid cancer were about 0.5 cases per million children per year. In areas of the Ukraine, this has risen to about 10 cases per million children per year and around Gomel to about 90 per million per year. There is a major discrepancy between estimates of thyroid cancer predicted using dosimetry together with standard risk-projection models and the magnitude of the increase that has actually been seen. One prediction at the April 1996 EC, IAEA, WHO conference in Vienna indicated that, considering the estimated thyroid-absorbed doses to all exposed populations in the first 10 years, there should have been 27 to 91 spontaneous cases and 9 to 21 radiation-induced cases for both children and adults. It appears that the excess of cases being seen in children is at least 10- to 50-fold higher than that predicted by current models which are largely based on results of other populations that have been exposed to external radiation.

There may be several factors that contribute to this discrepancy. Several hundred thousand thyroid measurements were taken on both children and adults shortly after the accident. These measurements were taken under great pressure with different types of instruments and may have had different methodologies (e.g., calibration, collimation, background contamination). They also were taken at various times after the accident. Even though dosimetrists have made an effort to account for these, errors by an uncertainty factor of 2 to 3 may still remain. Unfortunately, most of the children who actually developed thyroid cancer did not have measurements taken after the accident.

There are major questions about the relative contribution to the thyroid dose of the short-lived radioiodines. Since the gamma energies of the various iodine isotopes fall in a narrow range, it is often not possible to say how much of each was present in a specific thyroid even if a rough spectral measurement of total activity was performed. The biological effect of the short-lived radioiodines may differ from ^{131}I, with the short-lived radioisotopes decaying before there is incorporation into colloid and thus potentially causing more damage per rad to the parenchymal thyroid cells. The short physical half- lives of isotopes such as ^{133}I also deliver their dose over a shorter time, which may result in increased biological effectiveness and less radiation repair. The geographical area with the highest incidence of thyroid cancer in children (Gomel) was exposed early in the course of the accident and may have received a much higher percentage of short-lived radioiodines than did other areas.

The areas around the accident are known to be somewhat iodine-deficient. Based on data from eastern Poland, this may have resulted in thyroid radioiodine uptakes of iodine of about 40% or even up to 70%. This factor should be absorbed into the dose estimates that have been derived from thyroid measurement data rather than from environmental measurements. Typical dosimetry models derived from euthyroid iodine-sufficient populations would not account for increased retention and recirculation of the radioiodine under such conditions. Other issues that may be of importance are the size and shape of the thyroid in a young child that may not be accurately reflected in standard dosimetric models. Thyroid gland size varies sharply with age; it is about 1.5 grams at birth, 2.5 grams at 1 year and 6.1 grams at age 5. The choice of gland size for the dosimetry models could affect dose by a factor of about 4. Infants and children are also known to have a larger iodine space (liter/kg) and increased thyroid clearance of iodide relative to adults.

The increased radiosensitivity of children relative to adults has been demonstrated for thyroid cancer induction following external radiation exposure (thymic and tinea capitis radiation studies). This factor of about 3 to 5 is taken into account in the current risk projection models and should not account for the discrepancy between predicted and observed cancers. Hormonal factors likewise should have already been considered. Genetic susceptibility is currently an unknown factor, although it has been demonstrated in the tinea capitis studies that persons of Jewish ancestry were 2 to 8 times more sensitive to tumor induction. All of these issues remain to be clarified. The use of current dosimetry and projection models leads to future estimates of 4000 to 8000 thyroid cancer cases and (assuming 10% mortality) 400 to 800 deaths resulting from the Chernobyl accident. At the recent Vienna conference, it was pointed out that if the current ratio of actual to expected spontaneous cases continues, the number of thyroid cancer cases could reach 1000 per year when the cohort of exposed children reaches adulthood. Although not emphasized in Vienna, many of these cases might have been prevented if potassium iodide (KI) as a blocking agent had been available in a timely manner to the exposed population. Inquiries have shown that less than 20% of the population took KI as a blocking agent and parents have stated that even if it were available it might not have been given because of inadequate information and distrust of authority.

Availability of KI varies by country. National policies regarding the use of KI following reactor accidents remain unsettled. In the United States and several other countries, there are major logistical problems in distribution, although Poland distributed over 11 million doses of KI to children within 48 hours of notification. Currently, KI is available without a prescription at every pharmacy in Austria at a small cost and Sweden distributes blister packs of KI by mail.

Finally, all three international conferences have identified major psychosocial issues related to the accident. However, these are difficult to separate from economic, political and other problems.

Evacuation and relocation, as well as distrust engendered from secrecy and misinformation for the first months after the accident, are all felt to be major etiologies. In addition, economic issues were and continue to be major problems that were exacerbated by the dissolution of the Soviet Union. When the Soviet Union existed, benefits and compensation were demanded by the local authorities and have been given to over 3.5 million persons. Many persons receiving this compensation are today living in areas where the natural background radiation and the contamination together total less than annual radiation doses from natural background radiation in Europe. It is a continuing reminder and reinforcement of their psychosocial problems and economic dependency.

Further Reading

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