MEDICAL ASPECTS OF THE ACCIDENT AT CHERNOBYL

Dr. Massimo Tosti Balducci
Nuclear Medicine Operating Unit
Local Health Enterprise 9 - Grosseto

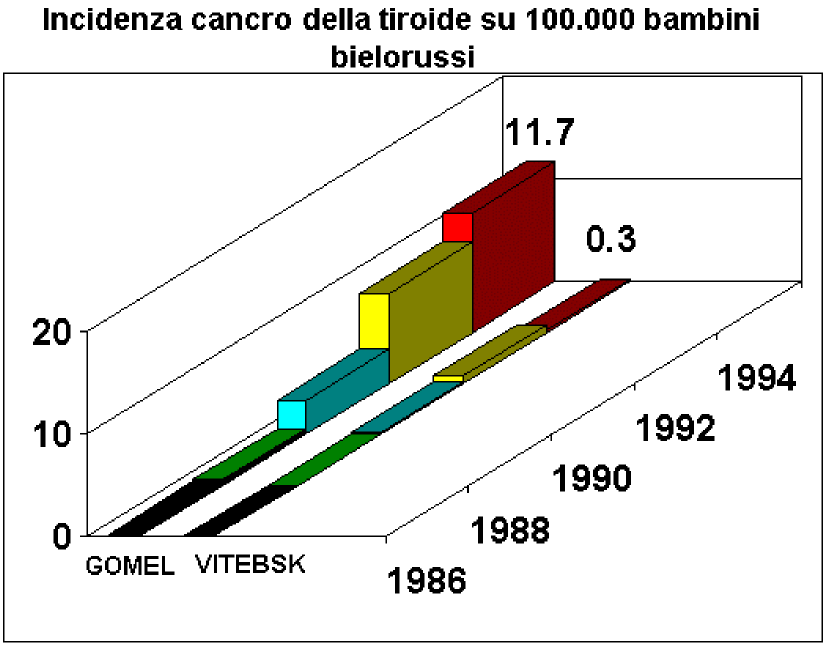
Following the explosion that took place in reactor no. IV of the power plant at Chernobyl and the subsequent conflagration, radioactive isotopes with a total radioactivity of 11 EBq were released.
To gain some idea of the order of magnitude involved, it may be considered that with the same quantity of radioactivity from radioactive iodine, about 60 billion scintiscans for the diagnosis of thyroid cancer could have been performed.
Of the main radionuclides released, those with the highest known biological impact were iodine (I131, I132, I134, I135), caesium (Cs134, Cs137) and strontium (Sr89, Sr90).
Leakage of these radioisotopes from the reactor did not take place only at the time of the explosion but went on for some length of time (until about 6 May) as radioactive gas, steam, dust and aerosol continued to escape.
Quantity released (EBq/day)
Days after start of accident - 26 April (source: IAEA, MODIF)
The largest particles fell within a radius of about 100 km from the power plant, provoking the majority of victims. Gases, finer dust particles and aerosol in the form of a "cloud" were carried by air currents to various parts of the globe, with the almost the only exception being the southern hemisphere. These elements then fell back to earth with precipitation. Distribution was extremely irregular, even in neighbouring areas.

The total dose of irradiation and contamination was determined by four factors:
CLOUD DOSE; from direct exposure to the radioactive cloud.

INHALED DOSE; from inhalation of radionuclides, part exhaled and part retained in the respiratory tract.
GROUND-LEVEL DOSE; from radioactivity deposited on the ground and other surfaces; dosage depends on the half-life of the radionuclides concerned as well as on length of stay in contaminated areas.
FOOD-CHAIN DOSE; from ingestion of contaminated foodstuffs and beverages.
total dose
In addition to the effects of irradiation and contamination in the immediate neighbourhood of the reactor, which involved the population resident in the vicinity of the power plant (about 120,000 people), power plant personnel and relief workers (about 800,000 people), fallout thousands of kilometres away from the site of the disaster has created problems related to lesions caused by an accumulation of whole-body (as in the case of Caesium) or organ-selective (thyroid for iodine; bones for strontium) contamination.

Table of estimated doses:
Relief workers; 170 mSv
Evacuees; thyroid: 1000 mSv in children < 3 years - 70 mSv in adults - whole body: 15 mSv
Residents of republics of the former Soviet Union; thyroid: 40,000 mSv in children from 0 to 7 years - whole body: from 5 to 250 mSv
Residents of Europe; thyroid: from 1 to 20 mSv in children-up to 4 mSv in adults - whole body: from 0.15 to 1.5 mSv
Residents of Italy; whole body: 0.38 mSv

The effects of ionizing radiation on living organisms are substantially distinguishable into two large groups: those where the effect depends on the dose received and for which there may be a threshold below which there is no effect at all; and those for which only the *probability* that the effect will manifest itself is a function of the dose received and for which there is no threshold level below which the effect will not occur. From this fundamental concept of radiobiology it follows that whereas it is relatively straightforward to establish the damage due to effects of the first type because there is a direct dose-response relationship (for example the induction of cataracts, non-neoplastic dermal lesions and lesions of the bone marrow or gonads), it is a much more complicated task to assess the second type of effect.
Any dose, no matter how small, may be sufficient to cause damage (for example genetic mutations or the induction of tumours). Before such potential effects actually occur, a substantial period of time may elapse. In addition there are many other variables to be considered (differences in diet, lifestyle, ethnic origin and so on) which can influence the emergence of the effect and it is therefore very difficult to attribute with absolute certainty the formation of a tumour to the action of a limited exposure to radiation.
The experience of radiation-induced lesions that has been acquired is based on experimental models, or on the consequences of atomic explosions (both in warfare and for nuclear tests), or on patients who have undergone ionizing radiation for therapeutic purposes. The accident at Chernobyl was therefore the only experience of its kind in terms of the quantity of radiation released and the number of persons affected either directly or indirectly by fallout. This means that many of the experimental models proposed for the calculation of risks to the population involved are not always applicable to the Chernobyl case.



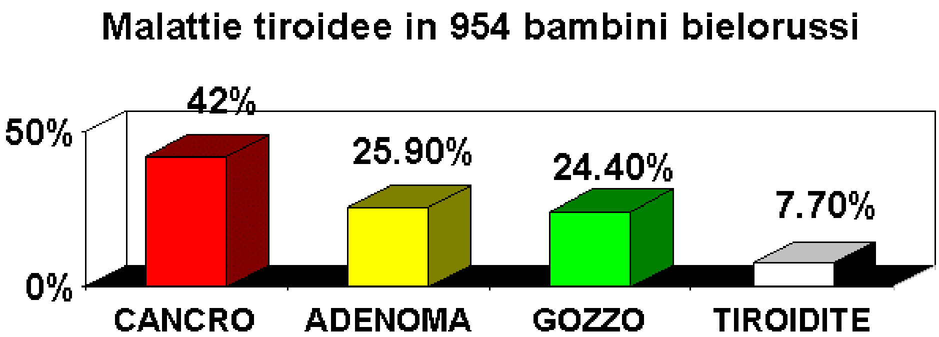
Of the organs most exposed to risk, the thyroid that has been studied in greatest depth because it demonstrates beyond any doubt the after-effects of the Chernobyl disaster. There are two reasons for this. The first is that iodine was one of the most significant, in terms of quantity, of the families of isotopes released. Iodine is normally absorbed by the thyroid gland, which uses it to form thyroid hormones. The second reason is related to the first and is to be found in the iodine deficiency that affects almost all the countries affected by fallout, including Italy. It is therefore easy to imagine that the thyroid glands of their inhabitants were only too ready to absorb the radioactive iodine present in the atmosphere, on the ground and in foodstuffs. These populations were thus at a greater risk than other groups also affected by fallout but resident in countries where iodine deficiency is compensated by systematic prophylaxis with stable iodine and where there was a lower likelihood of individuals' absorbing radioactive iodine. According to some Authors, iodine prophylaxis reduces the risk of the incidence of thyroid neoplasia in the population involved by a factor of 2-3.

Data currently available concern children in Belarus who resided in the regions that were most severely affected by the cloud of radioactive iodine. The incidence of thyroid cancer in this population increased from 0.3 to 11 cases per 100,000 inhabitants. In 1995, the total number of cases exceeded 400.

Varying incidence of thyroid cancer in Belarussian children from highly contaminated areas (Gomel) and non-contaminated areas (Vitebsk) (Courtesy of Prof. E. Demidchick)

Thyroid diseases in 954 Belarussian children cancer - adenoma - thyrocele - thyroiditis
(Courtesy of Prof. E. Demidchick)

Never before had such a large number of cases of thyroid cancer been detected, particularly bearing in mind that children are involved. The relationship of cause and effect with the accident at the Chernobyl power plant therefore seems self-evident. One aspect that took almost all researchers by surprise was the extremely short period of latency between exposure and the formation of neoplasms. It was much shorter than the expected latency of about 20 years. Moreover, cancers in these children appeared to be much more biologically aggressive than thyroid neoplasms in children who have not been exposed to radiation, despite the fact that the two forms of tumour are histologically similar. A recent study reports that on the basis of epidemiological projections, the number of cases of thyroid cancer expected in EEC countries is 618, of which 62 are expected to be fatal. To this must be added, however, the much higher number of children in the most seriously affected non-EEC countries (Ukraine, Belarus, Russia, Poland). Data abstracted from a report of the *Istituto Superiore di Sanità* (Italian Institute of Health) on the population of Italy predict, with all due reservations, the occurrence of about 60 fatal thyroid tumours over a period of about 30 years after the accident at Chernobyl. Taken by itself, the number may seem high but in fact if it is compared with the incidence of spontaneous neoplasms of the same type in Italy, it has a much lower significance. Indeed the figure is so low as to be indistinguishable from spontaneous thyroid tumours.



Some of the more controversial aspects of the effects of the disaster concern the possibility of induced non-neoplastic lesions of the thyroid gland. According to the previously mentioned study, EEC countries can expect 1855 cases of benign thyroid nodules and a high but unquantified number of cases of autoimmune thyroiditis. Opinions regarding these two illnesses are however divergent because their radiation-dependent status has by no means been conclusively demonstrated and they could be due to iodine deficiency. Nevertheless, there does appear to be a growing number of new cases of thyroiditis being recorded in Belarus. Finally, it remains to be decided whether the increased number of thyroid illnesses recorded after 1986 is due to greater attention being focused on research into these diseases and their constant monitoring.

It must in other words be clarified whether it is true or not that in the past thyroid diseases were present in the same distribution pattern but were not diagnosed because they were not studied with sufficient thoroughness. Nonetheless, the increased incidence of thyroid diseases with respect to the non-contaminated control population would appear to link unequivocally the higher incidence of thyroid cancer to the effects of the accident at Chernobyl.

The possible induction of neoplasms affecting organs other than the thyroid gland (particularly leukaemic diseases) is even more difficult to demonstrate or predict because of the impossibility of distinguishing such tumours from those formed by causes other than the radiation released by reactor no. IV. The same can be said of alterations of the immune system that might expose contaminated populations to a higher risk of autoimmunity-related diseases (diabetes, rheumatoid arthritis, thyroiditis) or infections. In practice, the diet poor in proteins and essential minerals that characterizes the most contaminated populations can play an equally important role. Once again, it is not possible to distinguish this role from the effects of contamination. In this regard, however, it is useful to remember a protein-poor diet lacking in "noble" elements will in any case reduce the effectiveness of the mechanisms that repair radiation-related damage to molecules and cells, thus making the entire body more vulnerable. In other words, if the children of Belarus could enjoy a better diet they would certainly suffer less injury as a result of the contamination to which they have been exposed. Children resident in the most seriously contaminated and economically underprivileged zones with an exclusively rural economy consume for the most part locally produced, and therefore highly contaminated, foodstuffs. These products are generally of insufficient nutritional quality, which creates a vicious circle that can lead to disease.

Apart from iodine, some of the other biologically significant radionuclides released by the reactor during the disaster have been particularly intensively studied. One of these is caesium. The two main isotopes of caesium present are caesium-134 and caesium-137, with half-lives of about 2 and 30 years respectively. Studies under way at the moment focus almost exclusively on caesium-137.

To evaluate the quantity of radiation absorbed, detectors are available that can estimate the quantity of radiation present in the entire human organism (whole body counters) or the radioactivity in biological liquids (urine).

Reduction in caesium content of urine over a 30-day stay in non-contaminated areas

urine on arrival - urine on departure

Work has been done on the subject that enables us to observe the extreme variability of the radioactivity detectable in children from Belarus, Russia and Ukraine. Presumably, this variability is due to differences in the children's diets. If a homogeneous group from a highly contaminated area with a rural economy is considered, where the diet is almost exclusively comprised of local foodstuffs, Cs-137 detection data for urine show uniformly high values which are significantly correlated with the quantity of Cs-137 present in the soil of the zone of origin. Moreover, values for Cs-137 in urine can be correlated to those obtained using the whole body counter, demonstrating that contamination extends over the entire body and that the detection systems used are appropriate.

At the present time, we know that caesium is eliminated by the body in the urine very quickly in the first few days but its excretion (which is higher in females than in males) subsequently becomes progressively slower. The period of time over which the body's content of this radionuclide falls by 50% (the biological half-life) is about 100 days. In the case of strontium, which accumulates in the bones, the biological half-life is about 50 years. This means that all the children who absorbed this radionuclide will continue to have a significant quantity of strontium in their bones even if they live to be 100.