The appreciation of radiation risks

The society we live in has become very conscious of the risks that beset us, but has yet to develop a consistent appreciation of the magnitude and significance of these risks. Perhaps it is unrealistic to expect such an appreciation, but professionals in the fields of health and safety have a duty to provide information in as clear and as fair a way as they can. The essential problem is the lack of quantification. Most of the features of our environment and of our life-styles are bad for us in excess. Some of them are bad for us at any level of exposure, but even these cannot be totally eliminated. Risks are endemic—the trick is to use our resources to reduce them, preferably giving priority to those risks that really threaten us and over which we have some real control.

To explain the consequences of exposure to ionising radiation it is necessary to provide a simple way of expressing exposures quantitatively and to give a simple account of the principal biological effects of such exposures. The quantity used to express the magnitude of an exposure to ionising radiation has the clumsy title of the effective dose equivalent, usually simplified to ‘dose’. It is a measure of the energy deposited in the tissues of the body with allowances for the variations in effectiveness of different radiations and for the different sensitivities of the tissues. Its unit, the sievert, is inconveniently large for most purposes; the millisievert, one thousandth of a sievert, is more useful.

Probably the best basis for appreciating the magnitude of doses is to use as a yardstick the natural background of radiation to which we are all exposed. Despite the widespread interest in radiation, especially since the accident at Chernobyl, few people seem to be aware of this background, which is due to cosmic rays and to natural radioactive materials in the soil and in our bodies. In addition, there is a substantial, and very variable, radiation dose to our lungs from the solid daughter products of the radioactive gas radon which seeps out of the ground into our houses. Excluding this localised exposure of the lungs, the natural background causes an annual dose to the whole body of about 1 millisievert. This dose may not be totally harmless, but it varies by a factor of two or three in different locations and the effect of these variations has not proved to be detectable, even in very large scale studies. The natural background thus provides a useful measure of radiation exposure for comparison purposes.

The biological effects of exposure to ionising radiation are almost certainly due to the energy deposited by radiation in, or very close to, the DNA in the living cell. The resulting changes are often repaired immediately, but may result in some damage to the DNA. This will sometimes prevent the cell from surviving or reproducing, but it may result in more subtle changes leaving the cell modified but viable. Most organs and tissues can cope with a substantial loss of cells without harm. At low and moderate doses, there is then no clinical effect due to cell killing. Above some threshold dose, injury is caused and the severity increases with dose. Virtually everyone exposed above the threshold suffers injury. If the damaged tissue is vital, the injury may be severe enough to cause death. Such injuries can be described as deterministic. Most of them appear shortly after the exposure.

A modified viable cell may be able to replicate and form a clone of modified cells. This can sometimes develop into a tumour in which the cell growth is uncontrolled — a cancer. Only very few of the cells affected by radiation result in a cancer because the body has at least two levels of defences. The molecular damage in the DNA may be repaired but, if it is not, the developing clone will almost always be recognised as foreign and destroyed or isolated by the next level of defences. Radiation effects such as cancer are called stochastic, meaning of a probabilistic nature. The probability of producing a cancer depends on the number of modified cells initially produced to challenge the defences and thus in turn depends on the dose. There is no sound basis for expecting a threshold, since even one modified cell might succeed in producing a cancer. Increasing the dose increases the probability of causing a cancer, but does not influence the severity. The delay between exposure and clinical outcome ranges from 2 or 3 years to many decades.

We know a good deal about the effects of large doses of radiation from studies of irradiated human populations such as the survivors at Hiroshima and Nagasaki and patients treated by radiotherapy. We know for certain that large doses of radiation cause serious tissue damage and that smaller, but still substantial, doses increase the subsequent incidence of cancer without causing overt deterministic effects. It is not easy to use the information obtained at high doses to give estimates of risk at the low doses to which we are exposed from background, from occupational exposure and from diagnostic radiology. The human data at low doses are inconclusive and the use of information obtained at high doses has to depend on biological studies on other animals and on cells in vitro. The probability of a radiation-induced cancer depends on the age of the exposed individual, but for a population of widely mixed ages and both sexes typical figures for the probability of death per unit dose are now thought to be between 3 and 5 chances in 100,000 per millisievert for prolonged exposure at low doses. On this basis, the natural background, excluding radon,
accounts for about 2,000 cancer deaths a year out of the 160,000 cancer deaths a year in the United Kingdom.

Popular interest is rarely stirred by exposures to natural background. Even headlines about radon, 'the killer gas in our homes', attract only transient attention. By contrast, there is continuing concern, and sometimes alarm, about the release of radioactive effluents to the environment and about proposals to bury solid radioactive wastes. It does not appear that these concerns are in any way influenced by the magnitude of the resulting radiation doses. Nevertheless, it is important that these magnitudes should be made known and that the implications for health should be presented. Because the exposures vary widely with the location and habits of the exposed individuals, it is necessary to consider the range of individual doses as well as the country-wide averages.

From time to time, the National Radiological Protection Board publishes reports and booklets that include data on the radiation doses from all the principal sources to which we are exposed. The Board's booklet, *Living with radiation*, successfully combines detailed information with simple explanations. Now in its 4th edition, it is available from HMSO and booksellers (ISBN 0 85951 320 3). A few key figures are worth noting. Some come from *Living with radiation*, others from more extensive reports of the Board.

Our yardstick, the annual dose from those natural sources that expose the whole body, is about 1 millisievert (mSv). It is made up of 0.25 mSv from cosmic rays, 0.35 mSv from gamma rays from the earth, and 0.30 mSv from natural radioactive materials in the body (mainly potassium). All these are typical values—the total for a few individuals is about 2 mSv in a year. None of these components can be significantly changed by any reasonable human actions. By contrast, the dose due to the radon in dwellings is very variable. On average, the annual dose amounts to about 1.2 mSv, but in some areas it is ten times this figure. The overall range is from about 0.3 mSv to about 100 mSv. There is as yet, however, no consistent evidence of any health effect due to this range of doses from radon in dwellings. If it is thought necessary, the higher exposures can be reduced by changes in the ventilation arrangements and by small structural changes in floors and foundations.

The diagnostic use of X-rays results in very non-uniform doses in individual patients and very wide variations from person to person. The annual country-wide average dose is currently estimated to be about 0.28 mSv, with dental X-rays and nuclear medicine bringing the total to about 0.5 mSv. The largest contributions come from examinations of the spine, the digestive system, and the urinary system. Some examinations result in doses to individual patients of a few tens of millisieverts, with higher local doses in the direct X-ray field. These doses are well justified by the benefits they bring to the patients, but there is still much that can be done to reduce doses by improved techniques.

Occupational exposures differ from job to job. The annual average doses, excluding those from radon in mines, range from about 2 mSv in the nuclear industry and in commercial flying down to about 0.1 mSv in research. Very few individual workers receive annual doses above 20 mSv. These doses have been reduced over the last decade or so and the trend is continuing.

The disposal of radioactive waste in the form of discharges of liquids and gases from nuclear plants, hospitals, and industrial premises causes doses that depend critically on the location and habits of those exposed. The annual country-wide average dose is less than 0.001 mSv, less than one thousandth of the dose from natural sources. The annual dose to a few individuals is higher, with a maximum in recent years of about 0.3 mSv. The annual average dose from the disposal of solid wastes is even smaller than that from liquid and gaseous wastes.

Together with some miscellaneous sources of exposure, such as air travel, radioactive consumer goods like luminous watches, and the burning of coal, these various sources deliver an annual average dose in the United Kingdom of about 2.5 mSv, of which 2.2 mSv is due to natural sources. We may not welcome these doses of ionising radiation, and they may indeed make some contribution to the overall incidence of cancer, but any such contribution is certainly small compared with other natural and man-made contributions. That gives no grounds for relaxing our present controls, but it does indicate that we have the control of our exposures to ionising radiation well in hand.

The benefits of the uses of radiation, particularly the medical uses, are of great value but, as with all human activities, there are associated risks. These risks are small compared with many of the other risks in our lives, and we should make sure that we do not allow the natural, but often excessive, even irrational, fear of radiation to prevent us from making proper use of the available benefits. Unfortunately, there are many who think it right to use fear to emphasise risks in which they have a special interest. Fear is easy to generate, but it is infectious and difficult to cure. It is also very unselective. It is only a small step from the fear of nuclear waste to the fear of nuclear medicine.

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