**Annotation**

**Diagnostic radiation risks**

X-rays are bad for you—how bad? I cannot hope to give a good, complete answer to a vexed question that is still baffling the experts. Instead I should like to present a personal view on some factors of concern.

**Radiation measurement**

Doctors do not always appreciate the essential point that absorbed radiation is measured as tissue concentration, not amount. The traditional unit is the rad, now to be superseded by the Gray (1 Gray = 100 rad). This measures radiation energy absorbed per unit mass of a particular tissue, in terms of joules per kg. Brewin has given various homely examples for clarifying this basic idea: I particularly like the notion of rainfall. 'Light rain over Britain' may add up to a considerable amount of rain over the whole island, but to anyone in London, Edinburgh, or Cardiff (or to any lightly irradiated tissue), that is of little concern; he will only need a light macintosh for protection. Similarly the inverse square law protects us because, like light, radiation is diluted as it spreads out. Doubling the distance between oneself and a radiation source results in one-quarter of the intensity of radiation at the new distance.

A quality factor can be used to correct for the different levels of damage inflicted on tissues by differing forms of radiation, for instance for the dense ionisation path of \( \alpha \)-particles. This leads to the dose equivalent unit of absorbed radiation, the rem. The new unit for this will be the Sievert. For \( \beta \), \( \gamma \), and \( x \)-rays this quality factor is 1, so here 1 rem = 1 rad, and 1 Sievert = 1 Gray.

**Natural background radiation**

Any discussion on radiation risks must take account of the energy absorbed by all of us from the earth below and the sky above. The gonad dose per person is about 100 mrad per year. There are local variations. Living in a stone house in Aberdeen may add up to 150 mrad a year compared with a brick house in London (30 mrad). In some places (for example, at certain South American and Indian sites), local doses may rise to 2000 mrad a year. These figures can be compared with tissue doses from a chest x-ray (perhaps 10 mrad) or an intravenous urogram (500–1000 mrad). Medical diagnostic irradiation is the second most important burden on populations after natural background radiation. Its level will vary with the medical habits in any country. In Western medicine Britain is comparatively frugal with x-ray examinations (400 per 1000 population per year). The estimated gonad dose here is about 20 mrad a year.

**Damage to the fetus**

The rapidly dividing cells of the fetus in its first trimester have been taken as some of the most radiosensitive tissues, and therefore as models for study and worry. There is still controversy about the ‘10-day rule’ advocated in Britain but not, for instance, in the USA. The rule is designed to postpone all nonurgent x-rays in women of childbearing age until the first 10 days of the next menstrual period, when a fertilised ovum cannot be at risk. In a careful review, Mole re-examined the estimated risks of malformations and cancer arising in a child who has been irradiated in utero. The overall risk of such a disaster after a 1000 mrad dose in the first 4 months of pregnancy is in the range 0–1 case per 1000. The natural level of risk that a pregnancy will result in a child with serious handicaps is at least 30 times higher.

Such calculations are no attempt to whitewash radiation risks, but rather to put that risk in the setting of the natural hazards we face. It may well be argued that a single additional man-made tragedy, however rare, is one too many. This argument assumes that most x-ray requests are frivolous, and have no bearing on the health or disease of the mother. If that appears a lopsided view, we ought to rethink the balance of benefit/risk for each individual.

On present evidence, the 10-day rule looks a sensible measure, provided it is not allowed to override the medical needs of adults rightly seen as potential mothers. We may justifiably be a little pleased that the NHS makes a good setting for this piece of medical practice, unlike systems of health care dominated by instant investigation demands.
The anxiety now engendered when a woman discovers she has been x-rayed during an early, unknown pregnancy is probably misplaced. Her doctors should help her to see the very small additional risk in the framework of the much greater natural hazards facing her pregnancy.

Why so much uncertainty about diagnostic radiation risks?

Calculations on the hazard from small x-ray doses are generally based on a hypothetical linear extrapolation of a known dose/risk relationship. At large radiation doses the necessary experimental data are to hand, but at the low dose levels of diagnostic irradiation the ground is not at all firm underfoot. As an example, we may accept that there is a proved relationship between the number of cigarettes smoked and the risk of lung cancer, in terms of so many dozens of cigarettes consumed each day. What is the additional risk of lung cancer after smoking, say, just one cigarette a day? At this dosage, natural variation in populations and in disease incidence swamp the effect we wish to measure. Our best present guess is to assume a linear relationship between the effect and presumed cause, even when that cause is decimated several fold. We cannot be sure.

What sort of x-rays?

There are great differences in the radiographic technique needed to make good x-ray images of different parts of the body. About 50 times as much x-ray exposure is needed for a lateral film of the spine as for a postero-anterior chest examination. Remember that we cannot jump to the conclusion that a child could have 50 chest x-rays for the radiation price of one lateral spine film; we are concerned with local tissue concentrations of absorbed energy (rads). But it does mean that the child who has to have repeated chest x-rays need not be worried about in the same way as the patient in whom we think we need 'follow-up spine films'. For a parenthesis, consider a child or an adult who falls on his bottom and is then x-rayed repeatedly for a suspected sacral fracture. There is no clinical pay-off to this diagnosis, and the radiation cost is heavy.

What sort of investigations?

In general, nuclear medicine investigations carry a very much smaller radiation burden than x-ray procedures. The clinical questions posed between the two are of course different. Looking to direct comparisons of an answering service provided by either high resolution, 'structural' radiographs, or by poorer resolution, 'functional' radionuclide scans may be fruitless, because we have overlooked the essential first step in diagnosis—asking the right questions. But some diagnostic pathways can be designed with radiation costs between the two very much in mind. The infant with a proved urinary infection probably needs a high resolution x-ray cystogram followed by a radionuclide renal scan, or possibly renal ultrasound. If all is well the intravenous urogram can be avoided. If he is found to have ureteric reflux, follow-up cystograms can be radionuclide investigations, because high resolution x-ray images are not required once bladder outflow obstruction has been ruled out by the initial examination. In very rough and ready terms, the radiation burden of nuclear medicine examinations is perhaps one-tenth or less of the 'corresponding' x-ray procedure.

Research and volunteers

The World Health Organisation has grappled with this thorny problem, in a public document that it coyly insists on designating unpublished. The British Institute of Radiology has endorsed the proposals in the form of guidelines,\(^5\) and the weekly medical journals have also commented.\(^6\)\(^\text{-}\)\(^7\) In brief, investigations are grouped into four categories of increasing radiation burden—only the two lowest are of interest here. Category II includes burdens of the order of 100 mrem—that is, equivalent to natural annual background irradiation. Category I is of the order of 10 mrem—that is, within the natural variation of background irradiation received in a year, for instance if a subject moved from one house to another. A chest or hand x-ray, or certain radionuclide investigations would be in this category. The guidelines suggest how investigators should approach such projects. There are protective, but perhaps not very helpful clauses concerning the age of subjects, particularly 'persons under 18 years of age should not be involved except when problems specific to their age groups are under investigation'. What else is paediatrics about?

The problems remain very difficult. I have no doubt that there should be much worry, discussion, and heart searching before a child (or his parent) is invited to participate in a radiation procedure not directly to his benefit. The investigator clearly has a crucial responsibility which cannot be shelved\(^1\) by approval from an ethical committee. Such approval is of course mandatory, and ethics-and-research committee might be a better name, because the link with science is important. An unscientific or trivial
study is not ethical. Experts have commented on the difficult legal questions affecting children.8-9

My conclusion is that there need no longer be an absolute automatic embargo on carefully judged studies involving radiation to children. Much expert advice will be needed, and so, to my thinking, will informed consent, with all its well-known drawbacks. I am surprised that the WHO report exempts the category I project of negligible risk from this absolute need. If I invite someone to walk through the rain with me, I would certainly ask whether he wants to do so rather than wait for a bus—not because I worry about his catching pneumonia, but because he (or his parents) might prefer to stay dry that morning. The fact that he is bound to get wet some time in the year is irrelevant. There is a large fund of altruism* in the human bank, and it would be stupid and perversely inhuman to stop drawing on it. Many individuals, children and parents, are delighted to be given a chance of showing just that. Part of our job is to prevent the unscrupulous investigator from tarnishing this bright coin, and to look after our volunteers jealously.

*Concise Oxford Dictionary's definition of altruism is 'regard for others as a principle of action'.

References

1 Brewin T B. When and how should we teach the basic concepts of radiation beam dosage? Br J Radiol 1977; 50:430-4.

THOMAS SHERWOOD
Department of Radiology,
Addenbrooke's Hospital,
Hills Road,
Cambridge CB2 2QQ