RADIATION HAZARDS *

J. K. McCabe, *President, Border Branch, Medical Association of South Africa, 1959*

In thinking about a suitable subject for this address I found that many of the possible choices have been ably dealt with in the past half-dozen years. The subject I have chosen appealed to me as one which has evinced much interest in our profession and among the general public during recent years. A great deal has been written on radiation hazards and risks have been frequently exaggerated, with the result that those not intimately connected with the use of ionizing radiations are apt to be confused by the welter of conflicting statements and opinions. As a profession our principal concern is with the delayed effects following diagnostic and therapeutic radiation. The most important of these effects are leukaemia and cancer.

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It is my intention to review some of the work that has been done on this subject. The Medical Research Council report on 'The hazards to man of nuclear and allied radiations',[1] which was published in 1956, is a very important contribution and much of what I shall say is drawn from this excellent report.

THE EFFECTS OF IONIZING RADIATIONS

Ionizing radiations of which the common types are X-rays, gamma rays, alpha and beta particles and neutrons, are so called because they give rise to the formation of electrically charged particles, ions, in the matter through which they pass. X-rays and gamma rays can penetrate the whole body and it is with these that we are chiefly concerned. The biological effects are dependent on the intensity of the radiation and the period of exposure.

The effects we have to consider are (*a*) somatic, involving cellular damage and destruction, and (*b*) genetic, due to gene mutations. Our knowledge of the effects on human beings has been gained by the study of:

(i) The use of X-rays and radium in the treatment of disease, mainly cancer;

(ii) occupational hazards of radiologists, workers in the luminizing industry, and miners of radio-active ores;

(iii) The study of the victims of atomic bomb explosions; and

(iv) experiments on animals.

Leukaemia

Let us first consider radiation-induced leukaemia.

1. *Atomic Bomb Explosions*

The Atomic Bomb Casualty Commission of the United States Research Council has recorded the incidence of leukaemia in Hiroshima and Nagasaki following the atomic bomb explosions. During the period 1947 - 1954 Moloney[2] reports 92 cases among survivors. Of these 39 suffered from chronic myelogenous leukaemia, 25 from acute myelogenous leukaemia, and 14 from acute lymphatic leukaemia. The expected incidence in the same cities in an unexposed population would have been 25.

It is interesting to note that in survivors who were 2,000 metres or more distant from the explosion, the incidence of leukaemia was 2 cases in every 10,000 persons, whereas for those under 1,000 metres distant the incidence was 128 per 10,000. The average time lag before the first appearance of symptoms was 6 years. The incidence remained approximately constant up to the 9th year.

2. *Deep X-ray Treatment of Ankylosing Spondylitis*

Court Brown and Doll[3] studied the incidence of leukaemia in 13 - 14,000 cases of ankylosing spondylitis treated with X-rays between 1933 and 1954. They found that the incidence increased with higher doses. The general incidence was approximately 10 times higher than the normal expectation, but was still only one-third of 1%. There was no increased incidence in a much smaller control series of 400 untreated cases. The latent period was about 6 years, similar to that in the Japanese cases, and the great majority were of the myeloid (not infrequently acute myeloblastic) type. In a later paper these authors concluded that the evidence suggested a linear relation between the cumulative dose of radiation and the biological effect—in this case leukaemia.[3] Burnet[4] quotes Faber in Denmark as having found an increased incidence of myeloid leukaemia in association with past exposure to X-rays, but not of chronic lymphatic leukaemia. Abbatt and Lea[5] stated that there was an association between leukaemia and non-irradiated ankylosing spondylitis, but they also considered

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that radiation plays a major part in the production of leukaemia in cases of ankylosing spondylitis. There is, in fact, no doubt of this. However, a proper perspective must be maintained and I cannot do better than quote the comment of Sir Macfarlane Burnet, chairman of the Australian National Radiation Advisory Committee: 'Perhaps the most important thing to remember about the results of this investigation is the rarity of leukaemia, even after heavy dosage'.[4] All authorities are agreed that deep X-ray therapy should continue to be used in the treatment of ankylosing spondylitis since the benefits conferred far outweigh the risks, and these will be significantly reduced by the more conservative approach to dosage and fields which has now been generally adopted.

3. *Leukaemia in Radiologists*

The incidence of leukaemia in American radiologists has been shown to be significantly higher than among their non-radiological colleagues (5 - 10 times) before the standards of protection were as high as they are now.[6,7] In view of this, a most interesting investigation was conducted by Court Brown and Doll[8] on behalf of the Medical Research Council. The expectation of life and mortality from cancer among British radiologists from 1897 to 1956 has been compared with those for comparable groups: (*a*) Social class I—an equivalent social group, and (*b*) doctors. These authors state in their summary: 'A study has been made of the causes of death of 1,377 male British radiologists (including Eire) during a 60-year period from 1897 to 1957. A comparison of the observed and expected numbers of deaths from all causes provides no evidence that occupational exposure to ionizing radiations has caused a detectable non-specific shortening of the expectation of life. This is particularly striking since the population includes most of the pioneer British radiologists, many of whom are known to have suffered from specific effects of over-exposure, that is, radiation dermatitis and skin cancer'.

However, there was a significant excess of cancer deaths in men entering the practice of radiology before 1921, the year in which the first committee to advise on protection was formed. The excess was confined to tumours of the skin and pancreas and (possibly) leukaemia.

There was no excessive mortality from cancer in men entering radiology after 1920, but it is perhaps a little early to make a full estimation of the hazard. There was an apparent increase in the incidence of leukaemia in the group, but the numbers were too small to justify conclusions.

4. *Leukaemia in Children*

The incidence of leukaemia (mostly acute) in children is highest between 3 and 4 years of age, reaching a peak (1950 - 1953) of about 60 per million.[9] Stewart and her co-workers[10] at Oxford published a preliminary report in 1956 which caused widespread anxiety regarding the apparent increased incidence in children irradiated *in utero* in the early months of pregnancy. In their subsequent paper in 1958[11] they gave the results of their completed survey of childhood malignancies. In this work they attempted to trace all the children in England and Wales who died of leukaemia or cancer before their 10th birthday (during the years 1953 - 1955) and to compare their pre-natal and post-natal experiences with those of healthy children. The total deaths consisted of 792 ascribed to leukaemia and 902 to other cancers (Registrar-General). Of the leukaemia group 677 and of the other cancers 739 were traced and the mothers interviewed.

It appeared from this work that children who have been X-rayed *in utero* are twice as likely to die of leukaemia or cancer before the age of 10, or, to put it another way, that 6 - 7% of all deaths from malignant disease before the age of 10 are due to abdominal X-ray examination of pregnant women. It was also considered that the frequency of exposure to X-rays in infancy was significantly higher for children, who subsequently died of leukaemia, than for other children. However, there was nothing to suggest that irradiation *in utero* explains the increase in recent years or the early peak of leukaemia mortality.

Further investigation is needed into the relation between low doses of radiation and the incidence of malignant disease, and into the radiosensitivity of the foetus as compared with the child and the adult. Possible genetic effects on the child have also to be taken into account. In the present state of our knowledge it is wise to avoid the abdominal irradiation of pregnant women where possible and to reduce it to the essentials where it is considered necessary.

5. *Leukaemia in General*

The (worldwide) incidence of leukaemia is increasing annually at the rate of about 4 - 5% *per annum*.[4] Last year Court Brown and Doll[12] published a paper on 'Adult leukaemia—trends in relation to aetiology'. They concluded that:

1. The apparent increase in mortality due to chronic lymphatic leukaemia and a great proportion of the increase attributed to other types at ages over 60 is due to better recognition of these diseases.

2. The observed increase in death rates from acute leukaemia at ages under 60 is largely real and is due to leukaemogenic factors. Acute and chronic myeloid leukaemia are the forms of the disease which radiation is known to induce.

Cancer

Chronic exposure is well known to cause epitheliomata which metastazise relatively early. By 1911 no less than 54 cases of cancer of the skin were reported in the early radiologists and technicians. The average latent period was about 13 years. The condition is rarely seen today in this group of persons, but does still occur in the untrained. Cancer is also known to occur in heavily irradiated areas with a latent period of 20 - 30 years. There is evidence suggesting that cancer of the thyroid may occur in children after irradiation of the thymus or after irradiation of the neck for simple conditions. Cancer of the thyroid has also been reported in adults previously irradiated for conditions such as tuberculous glands of the neck, with a latent period of about 20 years. By 1959, 7 cases of acute leukaemia were reported following the treatment of hyperthyroidism with radio-active iodine.[13] The general incidence of radiation-induced malignancy appears relatively small under modern conditions, and with increasing knowledge steps can be taken to reduce it still further.

Genetic Effects

Much experimental work has been done in this field with regard to plants and animals. Little is known of the genetic effects of radiation in human beings. Ionizing radiations are of genetic significance only in so far as they affect the reproductive cells in the reproductive organs and are, therefore, of no genetic significance in individuals beyond the reproductive age. Damage to genetic material is cumulative and irreversible. Natural background radiation is estimated to contribute about 3 r per generation to the gonadal dose and to account for something between 2 and 20% of human mutations. It is estimated that the level of genetically significant radiation currently received from diagnostic X-ray examinations in the United States is of about the same order of magnitude as that from natural background radiation;[14] in Britain it is thought to be higher than 22%. This is by far the most important source of possible genetic damage in peace time and therapeutic radiation is thought to be next. The major part is contributed by examinations and treatment of a relatively few sites in the body and, bearing this in mind, a great deal can be done to reduce the risk. The present contribution from sources such as radio-active fall-out, luminizing paints, etc. is relatively small. Current levels of gonadal radiation are not thought to constitute a serious genetic hazard to the population as a whole. The tale will be unfolded only by the study of future generations. It is our present obligation to take every care to avoid unnecessary exposure of the gonads in children and in individuals during their reproductive life.

There is no evidence that infertility is produced under modern conditions of occupational exposure, nor is there any evidence that menstrual disorders are caused.

Abuse of Diagnostic Radiation

My talk would be incomplete without reference to this unhappy aspect of the subject. Notwithstanding all that has been written in the past 40 years there are still colleagues untrained in radiology, who use diagnostic machines without regard to their own safety or that of their patients. Fractures are still being diagnosed and set under screen control using small portable units. Some tuberculosis clinics are still attempting to diagnose pulmonary tuberculosis by screening, in one case using up to 7 m.a.—more than twice the permissible milliamperage. Fingers are still being burned and avoidable lethal epitheliomata are still occurring. Dr. Maurice Weinbren,[15] who is a member of the Radiation Hazards Commission recently appointed by the Government, told me that he has seen examples of these incidents in recent months. The public

are becoming radiation-conscious and suits for damages are on the increase.

PROTECTION

It is obvious that it is the duty of all who use ionizing radiations in the diagnosis and treatment of disease to be thoroughly conversant with the accepted standards of protection and to be in possession of the international recommendations as amended from time to time. I might mention here that important contributions on protective measures have appeared in the South African literature.[16-18]

Points which require emphasis today include:

1. Careful coning, filtration, and shielding of the gonads in children.

2. Coning and shielding of the lower part of the trunk in examinations of the upper half of the body, to avoid irradiation of the gonads.

3. Cooperation between referring doctor and radiologist in assessing the indications for diagnostic X-ray examinations involving direct irradiation of the gonads. Radiation pelvimetries should rarely be necessary today, and abdominal irradiation of pregnant women should be reduced to the essential minimum.

4. Screening and major diagnostic procedures should be undertaken only by those with the necessary special training.

5. Avoidance, as far as possible, of the use of ionizing radiations in the treatment of non-malignant conditions in children, particularly about the head and neck and in the neighbourhood of the gonads, and in the treatment of non-malignant conditions involving irradiation of the gonads during reproductive life.

6. Radio-active isotopes should not be used for the treatment of non-malignant conditions in children and young people, and should be avoided where possible during reproductive life.

'The future development of civilization is bound up with the exploitation of nuclear energy. Its use, like that of other sources of energy, entails risk, but the risk is controllable and, within limits, can be accepted. It is the scale and not the nature of the hazard that is new, for human populations have always been exposed to natural radiation of low intensity'.[1]

CONCLUSION

Most of the important additions to our medical armamentarium since the turn of the century have had their associated hazards, and ionizing radiation is no exception. The enormous benefits far outweigh the risks. While there is no cause for alarm, there is certainly need for caution. The more we know of the nature and extent of the hazards, the better are we equipped to avoid them.

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REFERENCES

1. The hazards to man of nuclear and allied radiations (1956): Medical Research Council Report. London: H.M. Stationery Office.
2. Moloney, W.C. (1955): New Engl. J. Med., **253**, 88.
3. Court Brown, W. M. and Doll, R. (1957): Spec. Rep. Ser. Med. Res. Coun. (Lond.), No. 295.
4. Burnet, M. (1959): S. Afr. Practit., **4**, 27.
5. Abbatt, J. D. and Lea, A. J. (1958): Lancet, **2**, 880.
6. March, H. C. (1950): Amer. J. Med. Sci., **220**, 282.
7. Warren, S. J. (1956): J. Amer. Med. Assoc., **162**, 464.
8. Court Brown, W. M. and Doll, R. (1958): Brit. Med. J., **2**, 5090.
9. Hewitt, D. (1955): Brit. J. Prev. Soc. Med., **9**, 81.
10. Stewart, A., Webb, J., Giles, D. and Hewitt, D. (1956): Lancet, **2**, 447.
11. Stewart, A., Webb, J. and Hewitt, D. (1958): Brit. Med. J., **1**, 1495.
12. Court Brown, W. M. and Doll, R. (1959): *Ibid.* **1**, 1063.
13. Jacox, H. W. and Kligerman, M. M. (1960): *Year Book of Radiology 1959-60*. Chicago: Year Book Publishers.
14. Kaplan, H. S. (1958): Amer. J. Roentgenol., **80**, 696.
15. Weinbren, M. (1960): Personal communication.
16. Editorial (1957): Med. Proc., **3**, 413.
17. Fainsinger, M. H. (1957): *Ibid.*, **3**, 422.
18. Jackson, H. (1958): *Ibid.*, **4**, 541.