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EDITORIAL: THE HAZARDS OF MEDICAL IRRADIATION

ROBERT J. BLOOR, M.D.

Radiation is a toxic agent. This has been recognized for a half century as far as large quantities are concerned. The necrotizing effect on locally irradiated tissues and the lethal effect on the whole organism are known to layman and physician alike. The potential hazard of small exposures was first recognized from the cumulative effect noted in the pioneer radiologists, but again this involved large total doses. With further study the dose required to produce a recognizable effect has been found to be smaller and smaller. Even the low exposures in diagnostic procedures and the scattered radiation from therapeutic applications are not completely without hazard. The estimate that the medical use of radiation constitutes the single largest source of exposure to the population of this country has given rise to much concern.

Little is accurately known about the significance of small radiation doses. While there is evidence that exposure of certain parts of the body to as little as 5 to 10 rads may be damaging in some instances, the degree of this hazard, whether to the individual or the population, is not clear. One of the basic sources of this confusion is the uncertainty that exists regarding the dose-effect relationship at very low levels. Virtually all of the experimental and clinical studies have been done at dose levels above 100 r, with extrapolation of the results to the low dose region.

There are several questions regarding the relation of dose to effect with small exposures that have not been satisfactorily answered. Is there a threshold dose that must be exceeded, *i.e.*, must a certain quantity of radiation be given before any effect is produced, or is the reaction "non-threshold" with respect to dose? Will repeated doses of radiation cumulate by simple summation or is there a more complex relationship? Will the same increase in dose always produce the same increase in effect (*i.e.*, is the relationship linear) or will the dose-effect relationship be more complex (nonlinear)? Until these questions can be answered, our information must remain qualitative rather than quantitative, and we are unable to assign accurate values to our estimates of hazard.

The induction of mutations as a result of radiation exposure is generally regarded as a linear, nonthreshold reaction, and the effects of repeated doses are thought to be cumulative by simple summation. Extensive studies of this genetic effect have been carried out in insects and small mammals. It is quite certain from the correspondence of effects in various species that the same qualitative effects occur in man, but the quantitative dose relationships remain uncertain. Estimates of the amount of radiation necessary to double the spontaneous mutation rate range from 20 to 80 or 100 rads. The greatest proportion of mutations are recessive; hence a mutated gene from one parent must join with a mutated gene from the other parent before the changed characteristic will be evident in the offspring. The frequency with which such junction can occur depends upon the number of mutations present in the breeding population. Thus the average radiation dose received by a breeding

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population is more important than that received by any one person. Mutation occurring after an individual's last child is conceived is of no significance either to the population or to his descendants.

Induction of neoplastic changes in body tissues is known to occur after exposure to moderate or large quantities of radiation. The evidence that this can occur at low radiation rates and total doses is largely indirect and depends heavily on the assumption that the dose-effect relationship is linear at all levels and without threshold. Actually, on the basis of experimental studies of the induction of cancer and leukemia, there are equally good reasons for considering this relationship as nonlinear or having a threshold. At any rate, because neither situation can be proved, the possibility exists that doses in the diagnostic exposure range might contribute to the induction of neoplasia and that this must be taken into account as a possible hazard. There is reason to think that infants and children may be more sensitive in this respect and therefore justify special consideration.

Shortening of the life span of experimental animals has been observed after prolonged irradiation at low dose rates. This is nonspecific in character without preponderance of any particular lesion. Attempts to evaluate this effect in man by consideration of the relative longevity of radiologists and other physicians has been inconclusive. At the present time there are insufficient data regarding this reaction in man to permit any estimate of the significance of the phenomenon clinically. It can probably be disregarded as far as medical exposure is concerned, though it must still be considered in relation to occupational exposure.

Production of fetal damage by irradiation in early pregnancy appears to present a more significant hazard than those so far mentioned. Doses of 5 to 10 rads applied to the mother during the early cleavage phases of the fertilized ovum can be shown to reduce litter size in experimental animals. Such doses will also increase the incidence of malformation to a measurable degree in the surviving fetuses. There is a reduction in this sensitivity with time of gestation; it remains higher in the first trimester than during the remainder of pregnancy. Women in the child-bearing age who may be pregnant thus constitute a particular problem. The recommendation that radiation exposure to the pelvis be avoided in such women except during the time from the onset of menstruation to the time of ovulation seems well taken.

Despite these uncertainties, quantitative estimates of radiation hazard have been made which can serve as a guide in practice. The most generally accepted estimate concerning genetic effect is that exposure of the gonads to 50 rads will double the spontaneous rate of mutation. The number of abnormalities that will appear in a population depends on the number of mutated genes present. There is an equilibrium between mutation induction and spontaneous loss. Thus to double the number of mutationally produced abnormalities would require exposure of an entire population to an average dose of 50 rads for the twenty to thirty generations necessary to establish equilibrium. Estimation of leukemogenic hazard depends on acceptance of a linear, nonthreshold relationship between dose and effect which is not on completely firm ground. On this basis, one can estimate that a dose of 30 rads to the whole hemato-
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The meticulous and elegant studies that are being carried out by the physics group at Memorial Center in New York do much to dispel this lack. The reader is referred to the paper by Epp, Weiss, and Laughlin, which reports measurements of dose to the hematopoietic system resulting from chest examinations, and to a study by Holodny, Lechtman, and Laughlin on bone-marrow exposure during the application of radioactive materials to pelvic cancer (to appear in Radiology for July). These studies supply much needed data for evaluation of marrow exposure and leukemia hazard.

General patient exposure resulting from therapeutic irradiation appears to present a lesser problem. The radiation beams used are small and well collimated. A very high proportion of patients receiving such treatment are beyond the age when reproduction is possible. The greatest use of radiation therapeutically is in the treatment of cancer. The danger to life from the patient’s malignant tumor is much...
greater than that from the effects of radiation even if the possibility of the induction of cancer were much greater than it appears to be on clinical grounds.

Cancer is relatively rare in children and young adults, but this is the group in which gonadal exposure should be minimized. The papers by Kaplan, Collica, and Rubenfeld and by Gwinn, Gastineau, and Campbell in this issue of Radiology deal with the gonadal irradiation resulting from therapeutic application. The first presents tables relating gonadal exposure to field size and location for middle-energy x-rays. The value of local gonadal shielding is shown to be appreciable even with the well collimated beams used therapeutically. As would be expected, treatment of areas well removed from the gonadal region results in little genetic hazard. The paper by Gwinn et al. is concerned particularly with the irradiation of children. Using phantoms constructed to represent typical children of three ages, they studied gonadal dose from a variety of therapeutic procedures that had been used in their department. The dose received in the region of the reproductive organs in these various phantoms was quite low for most procedures. Treatment of the proximal femur in the male or the retroperitoneal region in the female were the only procedures delivering more than 50 rads to this critical area.

Very few objective data are available concerning the exposure received by the general population. The estimate that medical uses of radiation constitute the greatest source of such exposure, referred to earlier, is based on several assumptions. The paper by Morgan in this issue describes a measuring device that is simple to use which would permit the collection of exposure data on every patient receiving any diagnostic examination. A continuous record of such exposures on all patients in one or more departments would help materially in supplying population exposure data.

There is reason to suspect that radiation exposure even in the small amounts associated with diagnostic radiology may have some deleterious effects either on the individual or on the genetic constitution of the human race. The degree of this hazard cannot be defined from the information available. Each physician responsible for the operation of equipment used in medical radiology should make every effort to use technics that have been shown to reduce exposure, but should not hesitate to perform an examination that will be of clinical benefit to the patient. Particular care is necessary in the exposure of women in the reproductive age.

The use of radiation diagnostically and therapeutically is essential to the present-day practice of medicine. It should be used with care and with knowledge of the possible hazards. In this way it will continue to be of greater benefit than hazard.

REFERENCE