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A REASONABLE ATTITUDE TOWARD THE MEDICAL USE OF DIAGNOSTIC RADIATION

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From the beginning of life man and his phylogenetic predecessors have been immersed in a sea of radiation. Indeed, it seems likely that the natural radioactivity at the level of the earth's crust has been steadily decreasing since the formation of the earth. Present concern with the effect of radiation upon humanity thus is a consideration not of a new agent, but rather of what effect a quantitative difference may cause.

The study of this field necessarily is divided into the problem of the effects of radiation on the individual and that of the genetic effects on the future of the race. The genetic aspect will be considered first.

In order to form an idea of the magnitude of this change in incident radiation and to form an idea of its relationship to what mankind has been receiving previously, the components of "natural" radiation will be examined.

The most penetrating radiation is that of cosmic rays, which deliver approximately 0.028 rad* per year.³ Gamma radiation from our natural surroundings is highest in brick and concrete houses and certain buildings made of granite.¹⁰ This delivers approximately 0.043 rad per year, but can go as high as 0.3 rad per year.¹² The activity due to radon in the air contributes 0.011 rad per year.⁸

Radiation from our own tissues is delivered by Potassium 40 (0.02 rad per year) Carbon 14 (0.001 rad per year) and Radon and its disintegration products in the tissues (0.002 rad per year).⁸ The total dose per year is thus about 0.095 rads and the total dose to age 30 to either gonads or other tissues is approximately 2.85 rads.⁸ Since the only radiation of genetic importance is that received prior to parenthood and the average age at parenthood is 30 years, the significant figure is the 30 year gonadal dose. This information is summarized in the accompanying Table I.⁸

Our current civilization imposes additional radiation upon the bone marrow and genes of mankind, the greatest source of which is without doubt the medical use of diagnostic roentgen examinations. The minimum estimates for the population dose of this radiation per year range from a low of 22 mr, arrived at in the area of Leeds¹² to estimates of 100 mr made for this country.⁹ Radiation from fluoroscopic shoe fitting, luminous watches and clocks, television sets and high altitude flying are all small. Occupational exposure in radiology and industry and atomic energy personnel exposures contribute less than 2 mr per year;⁹ this is summarized in Table II.

*The rad is a unit of absorbed dose and thus a more biologically significant unit than the "r" or incident dose. Whenever possible rads will be used as the unit, but where no such data is available, the "r" will be used. 1 rad = 1000 millirad. 1 "r" = 1000 mr.

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TABLE I. (TABLE 4J REPRODUCED FROM THE REPORT OF THE MEDICAL RESEARCH COUNCIL OF GREAT BRITAIN⁹)

Dose-rates to the gonads for a region of 'normal' ground radioactivity

RADIATION SOURCE	DOSE TO GONADS PER YEAR (rad)
EXTERNAL IRRADIATION	
Cosmic rays (sea level)	0.028
Local gamma rays (Leeds, 78 millirad/year indoors	
48 millirad/year out-of-doors	0.043
Radon in air, $3 \times 10^{-12}\text{c}/1$	0.001
INTERNAL IRRADIATION	
Postassium 40	0.020
Carbon 14	0.001
Radon + disintegration products, $3 \times 10^{-12}\text{c}/1$	0.002
Total dose per year	0.095 [†]
Dose to age 30 years	2.85 [†]

[†] Includes allowance for the R. B. E. of the alpha radiation where present, and therefore also expresses the gonad-dose in rem.

TABLE II. (TABLE 4 REPRODUCED FROM THE REPORT OF THE MEDICAL RESEARCH COUNCIL OF GREAT BRITAIN⁹)

Summary of estimated population doses of radiation to the gonads expressed as percentages of natural background

SOURCE OF RADIATION	Approximate dose to gonads as a percentage of natural background
Natural background	100
Diagnostic radiology	at least 22
Radiotherapy	?
Shoe-fitting	0.1
Luminous watches and clocks	1
Television sets	much less than 1
High altitude flying	insignificant
Occupational exposure:	
Radiology and Industry	at least 1.6
Atomic Energy Authority	0.1
Fall-out from test explosions	less than 1

Diagnostic Radiation

If weapons testing is continued at the rate of the last 5 years, the estimated yearly gonadal dose in this country is 3 mr, but if it were to proceed at the higher levels of 1953 and 1955 this dose would be multiplied⁹ by 2. The total of these radiations is thus slightly above the natural background.

The application of radiation results in the acceleration of the evolutionary process and since more unfavorable mutations are produced than favorable ones, an increase in the process of natural selection results. The best estimate which can be made at this time of the dose of radiation which, if administered continuously to the entire population for 100 generations, would cause a doubling of the amount of clinically apparent mutation is 50 rads gonadal dose by age 30.^{2,9} The one generation effect of this dose, however, would produce a barely detectable clinical increase in mutation, being of the order of 2-3%.⁹ Roughly 4-5% of all live births in the United States have defects and of all these it is estimated that half or about 2% of the total of live births have defects of genetic origin.⁹ Doubling mutation rates of both parents would add an additional 0.2% to the present chance of producing a defective child.

Though 50 rads is an acceptable dose for a very small fraction of the population, 10 rads is suggested as the top limit for the whole population.^{9,9} The current dose is 4 rads. At present dose levels about 0.01% of the new generation or 1/10,000 bears some defect due to "civilization" radiation compared to 800/10,000 who are stillborn or malformed due to other causes.⁹ The wide dispersion of latent mutations makes the average dose that the whole population receives the important figure, rather than dose to individuals.

The second aspect is the effect of radiation on the individual. Accidental exposures and exposures during time of war indicate that when a population is subjected to a dose between 400 and 600 r total body radiation half of them will succumb. At the other end of the time scale is the chronic small dose exposure received by those whose occupation brings them into contact with radium and x-ray. There is an increased mortality among radiologists due to leukemia, which indicates an examination of the relationship of leukemia to radiation. This has been done best by E. B. Lewis⁵ who has correlated data from four groups of individuals. These groups are first, survivors of the atomic bomb radiation in Japan; second, patients radiated for ankylosing spondylitis; third, children radiated as infants for thymic enlargement and fourth, radiologists.

When one plots the incidence of leukemia among the survivors of Hiroshima and Nagasaki in comparison with the distance of the individuals from the hypocenter, and thus the dose which they received, one finds a relatively constant value for the probability of acquiring leukemia of 2×10^{-6} per individual per rad per year. Thus if an individual receives a total body dose of 100 rads, his chance of dying of leukemia is 200 out of a million.

Court Brown and Doll⁸ have studied the incidence of leukemia among patients treated with x-rays for ankylosing spondylitis. Of 11,287 patients irradiated during the period of 1935 to 1954, 37 developed leukemia. In this situation as well, the dose

of radiation delivered to the red marrow increased the incidence of leukemia in proportional fashion and produced a remarkably similar value of probability of developing leukemia.

Simpson, Hemplemann and Fuller¹¹ traced 1,400 individual infants who had been given radiation for enlarged thymus and a control group of unirradiated siblings. In this group there were 7 confirmed cases of leukemia with none in the controls. The number of cases expected in this treated population is 0.6. This gives a remarkably similar probability value.⁵

March⁶ called attention to the increased incidence of leukemia in radiologists in 1944, and at the time of his second report in 1950 had collected a total of 14 deaths. Subjecting this information to the same type of analysis, similar probability value is obtained.

Recent publicity in the public press has stressed the hazard of radiation and has neglected to consider the benefits derived from this type of medical examination. Asymptomatic individuals over the age of 50 show a 0.2% incidence of cancer alone.¹³ At this time the hazards of neglecting proper roentgen diagnostic studies are considerably greater than the hazard of genetic damage or leukemia.

SUMMARY

1. The production of mutations by radiation absorbed by the gonads prior to parenthood is a linear function of the quantity of radiation without any evidence of a threshold effect.
2. The incidence of clinically apparent mutations induced at the present rate of utilization of diagnostic medical x-rays and present quantity of fall-out from nuclear explosions is predictable with considerable certainty as approximately 1/10,000 new births compared to 800/10,000 stillborn or malformed due to other causes.
3. Those procedures which produce a particularly high dose to the patient, such as pelvimetry, should be carefully re-evaluated both for possible improvements in technique and for indications.
4. The probability of an individual developing leukemia, in addition to the spontaneous incidence, appears to be a direct function of the amount of radiation absorbed by him, again without a threshold level, but with a linear relationship between radiation absorbed by the bone marrow and frequency of leukemia.
5. The advantage from diagnostic roentgen studies at the present time is far greater than the hazards of leukemia. The current publicity concerning radiation hazards has neglected to mention the considerable benefit to many patients from such studies.

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