

Margulis has summarized very well our response to such evidence. "A conservative approach of assuming linearity to the lowest dose is the only logical and responsible policy . . . There is a definite risk of radiation in these mutations even in the diagnostic range . . . a dose of radiation to patients in the reproductive age should therefore be kept as low as possible. It is an interesting thought that even though the risk may be acceptable for a particular individual because valuable diagnostic information may be forthcoming, the price of this risk will be paid by the progeny and not by the individual who is obtaining the benefit. Since most mutations are recessive and not manifested in the first generation, this price may not be paid for some time. Although radiologists have recommended radiation protection measures since 1916, there has been a great deal of delay in enacting them". (Margulis, 1973).

As stated in the BEIR report, "risk estimate and cost-benefit analysis are needed for decision-making. Even if the benefit outweighs the biological cost, it is in the public interest that the latter must still be reduced to the extent possible". Their subcommittee has calculated that an exposure of 5 rem per generation would increase the equilibrium ill-health incidence by .5 to 5.0%, depending on whether the mutation doubling dose in humans is 200 rem or 20 rem, the calculated extremes.

Joshua Lederberg, a 1958 Nobel Prize winner, attempted to measure the economic cost of radiation. Such calculations are controversial but thought-provoking, and I would like to paraphrase his evidence beginning with two established facts:

- a) that overt genetic disease affects about 2% of newborns.
- b) that background radiation is on the average about .1 R per year.

One then makes three assumptions:

1. Many diseases, perhaps accounting for 20% of our health bills, are genetic (mutational) in origin. When one considers that some of the ~~many~~ people with overt genetic disease require long institutionalization and that schizophrenia, diabetes and atherosclerosis have major genetic components, one can imagine a total of 10% of illness and 20% of our health bills.
2. Background radiation has caused 10% of mutations (there is no way to measure or confirm this but some geneticists believe it plausible).
3. The human gene pool retains an accumulation of 10 generations' worth of deleterious mutations - mutation requires 10 generations to come into equilibrium.

The genetic cost of ill-health is therefore $10/100$ (percent from background) $\times 1/10$ (one generation) $\times 20/100$ (share of genetic component) = $1/500$ or .2% of our health bill. If this background radiation of .1 R has already caused .2% of our health bill, then 1 R of extra radiation might add 2% to our health bill. In case we have over-calculated, let us accept half this amount as an upper figure and assume that the lower figure might vary by one order of magnitude. On this basis, somewhere between .1 and 1.0% of our health expenditures might be added by 1 R of radiation.

The BEIR subcommittee then translated this into dollars. The average per capita cost for medical care and hospitalization and drugs is \$400 per year. (The United States population of 200 million had estimated 80 billion medical expenses in 1970). If we take a generation at 30 years, the \$400 of 1970 value would total \$12,000 per person.

One R of radiation, continued until equilibrium is reached would add an amount of illness equivalent to a cost of \$12 to \$120 per person.

Thus a \$30 radiologic examination such as an IVP or Barium Enema, might result in a 1 R gonadal dose and do in the long run \$30 or more of damage to health through genetic damage alone - without including the risk of new tumor initiation, which might be 1 in 10,000, and has not even been considered in the above calculations.

In summary, every radiograph does a little harm, especially those ~~prior~~ ^{during} to ~~the end of the~~ reproductive life. One would hope that each such examination is chosen wisely to produce a definite benefit that aids the short term management of the patient, to compensate for the long-term risk to the gene pool, and the slight risk of carcinogenesis.

Implications of the above evidence of radiation damage, related to specific and long overdue changes indicated in medical and radiological practice, will be discussed in a subsequent article.