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Title: RADIATION AND RISK: A LOOK AT THE DATA

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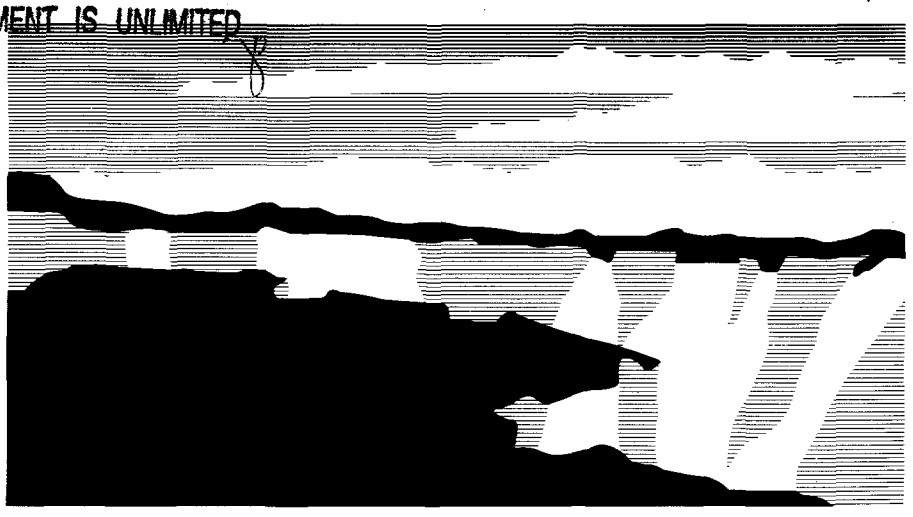

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Radiation and Risk: A Look at the Data, *Mario E. Schillaci (LANL)*

INTRODUCTION

This paper is a review of current data on the risks associated with human exposure to ionizing radiation. We examine these risks for dose levels ranging from very high (atomic bomb survivors) to very low (background). The principal end point considered is cancer mortality. Cancer is the only observed clinical manifestation of radiation-induced stochastic effects. Stochastic effects are caused by subtle radiation-induced cellular changes (DNA mutations) that are random in nature and have no threshold dose (assuming less than perfect repair). The probability of such effects increases with dose, but the severity does not. The time required for cancer to develop ranges from several years for leukemia to decades for solid tumors. In addition to somatic cells, radiation can also damage germ cells (ova and sperm) to produce hereditary effects, which are also classified as stochastic. However, clinical manifestations of such effects have not been observed in humans at a statistically significant level.

ATOMIC BOMB SURVIVORS

Perhaps, the best source of data on the radiation induction of cancer in humans is the Life Span Study[1] of survivors of the atomic bombings of Hiroshima and Nagasaki. The data on cancer mortality cover the period 1950-1987 and include more than 86,000 individuals. Those cancers for which statistically significant (90% confidence) effects were seen for cancer mortality include (in decreasing order of risk): leukemia, multiple myeloma, breast, bladder, lung, colon, liver, and stomach.

Statistically significant effects were not seen for cancers of the esophagus, bone and connective tissue, and brain and central nervous system.

The total number of solid-tumor deaths expected in the time period, based on comparison with the 1985 total Japanese population, is 6582, whereas the number observed is 6887. It is noteworthy that, of more than 86,000 persons who survived exposure to these nuclear weapons detonations in 1945, only 305, or 0.35%, are estimated to have died from radiation-induced solid cancers in the period 1950-1987.

A plot of excess relative risk versus mean weighted equivalent dose for these data is fit nicely by a straight-line from the origin with a slope of 0.45 Sv^{-1}. [Excess relative risk (ERR) is defined in terms of the observed number of deaths (O) and the expected number (E) as ERR=O/E-1.] However, it should be noted that the first data point that shows a significant (90% confidence) effect is that for the dose range 0.20-0.50 Gy, or a mean weighted equivalent dose of 0.33 Sv. Multiplying this slope by the solid-tumor mortality rate (0.243) in the 1985 population yields the risk factor for radiation-induced solid-tumor mortality of 0.11 Sv^{-1}. Including leukemia, the risk factor rises to 0.12 Sv^{-1}, which is appropriate for high-dose, high-dose-rate exposures.

How are these results to be applied to low-dose, low-dose-rate exposures that are of principal interest? The 1990 Recommendations of the ICRP[2] (ICRP Publication 60) include a reduction (called a Dose and Dose Rate Effectiveness Factor, or DDREF) for low-LET radiation of a factor of 2 for absorbed doses below 0.2 Gy or for dose rates below 0.1 Gy per hour. Based on consideration of

atomic bomb survivor data available at the time of the recommendations, as well as other data, particularly medical exposures, the ICRP determined the risk factor for low doses or low dose rates to be 0.04 Sv^{-1} for workers and 0.05 Sv^{-1} for the general population, which includes children. UNSCEAR, in its 1993 report[3], recommends a DDREF of "probably no more than 3" for doses below 0.2 Gy or for dose rates below 0.006 Gy per hour.

NUCLEAR WORKERS

The International Agency for Research on Cancer (IARC) Study Group on Cancer Risk among Nuclear Industry Workers recently performed a study of combined data from the United Kingdom, the United States, and Canada. This important study[4], which included more than 95,000 nuclear workers, is the most extensive study to date for cancer mortality risk associated with protracted exposure to low levels of radiation. Workers who received greater than 0.25 Sv in a single year were excluded. The results of this study show "no evidence of an association between radiation dose and mortality from all causes or from all cancers." Although a claim is made for a significant association between radiation dose and mortality from leukemia, a close examination of the data reveals that only for doses greater than 0.40 Sv is this risk significantly different from zero.

NATURAL BACKGROUND

A Chinese study[5], covering the period 1970-1985, in Guangdong Province, represents the most extensive study to date on the health effects of natural background radiation. This study involved about 70,000 individuals from two very stable populations from neighboring regions in which a difference in annual equivalent dose of 0.002-0.003 Sv was associated with deposits of thorium-rich

monazite sands. Based on estimates from the Japanese Life Span Study (omitting the DDREF), an excess risk for leukemia incidence of 27% by age 50 years would be expected for the group with higher annual dose. However, the leukemia mortality rate in this group was lower than in the control group, though the difference was not statistically significant.

CONCLUSIONS

The atomic bomb survivor data clearly indicate a linear dose-effect relationship for acute exposures above 0.2-0.5 Gy. Below about 0.2 Gy, there are no significant data to support an association between absorbed dose and cancer mortality. Generally, the data are inconclusive at such low doses.

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1. "Sources and Effects of Ionizing Radiation," Annex A and references contained therein, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 1994 Report to the General Assembly, United Nations, New York, 1994.
2. "1990 Recommendations of the International Commission on Radiological Protection," paragraphs 74 and 83, ICRP Publication 60, Pergamon Press, Oxford, 1991.
3. "Sources and Effects of Ionizing Radiation," Annex F, paragraphs 357-362, UNSCEAR 1993 Report to the General Assembly, United Nations, New York, 1993.
4. E. CARDIS *et al.*, "Effects of Low Doses and Low Dose Rates of External Ionizing Radiation: Cancer Mortality among Nuclear Industry Workers in Three Countries," Radiat. Res. **142**, 117 (1995). See also Mario E. Schillaci, Comments, Radiat. Res. **145**, 647 (1996).
5. L. WEI *et al.*,"Epidemiological Investigation of Radiological Effects in High Background Areas of Yangjiang, China, J. Radiat. Res. **31**, 119 (1990).