GUEST EDITORIAL

This guest editorial (the second) is contributed by Rosalyn S. Yalow, Ph.D. She earned her Ph.D. in Nuclear Physics at the University of Illinois in 1945 and has had a most distinguished scientific career: only a few of the highlights can be mentioned here. In 1977 she was awarded the Nobel Prize in Physiology or Medicine for the development of radioimmunoassay, a methodology which is used in laboratories around the world to measure hundreds of substances in blood of biological interest. In 1988 she received the National Medal of Science. She has been at the Bronx Veterans Administration Medical Center since 1947 and is a VA Senior Medical Investigator, and is also the Solomon A. Berson Distinguished Professor-At-Large of the Mount Sinai School of Medicine. She has received over 40 honorary doctorates from universities around the world. Dr. Yalow was a founding member of the AAPM, and is a Fellow and Honorary member of the AAPM. In this editorial, Dr. Yalow writes on a subject of great concern to her and of direct interest to our membership. Dr. Yalow is always constructive and original. She does not hesitate to state her case even though she knows it may be controversial in some areas, and it is always carried out with her constant good humor. We are all very indebted to Dr. Yalow, as a most distinguished pioneer in medical physics, for the following presentation on a subject of concern to all medical physicists.

John S. Laughlin

The contributions of medical physicists to radiation phobia

This title is deliberately provocative. However it can be broadened to refer not only to medical physicists but also to the great majority of scientists who should be knowledgeable about the biologic effects of low level radiation, but who have not been actively engaged in educating the public and politicians about these effects. There is a small group of scientists whose public pronouncements and appearances at radiation-injury trials would suggest very high levels of radiation injury associated with levels of radiation not much in excess of variations in natural background radiation. It is unfortunate that Senator Metzenbaum entered into the Congressional Record (S-8760: June 26, 1986) a prediction by John Gofman that there would be 14 710 leukemia deaths as a consequence of the fallout from Chernobyl. It gave official credence to what is obviously an exaggerated prediction. Such a prediction was certainly inconsistent with an increase through 1978 of only 90 leukemia deaths among the 80 000 survivors of the Hiroshima–Nagasaki bombing.[1] Subsequently, Dr. Gofman predicted[2] that one could expect 13 100 to 19 500 leukemia deaths as a consequence of the deposition of cesium around the world. In his paper he indicated that there would be 1 100 leukemia deaths in West Germany alone as a consequence of an integrated dose of 115 mrads, 50% of which would have been received in the first ten years after the accident. Through our organizations and as individuals we should be better organized to combat such misinformation that is so pervasive throughout the media and which influences public beliefs and legislative action.

My more fundamental concern arises from the damage done by our accepting and even promoting the person–rem concept as the scientifically credible basis for predicting radiation-related malignancies. Implicit in the acceptance of

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this concept is the validity of the linear-extrapolation hypothesis, which implies that there is no dose–rate effect for injury from low linear energy transfer (LET) radiation and no threshold for radiation-induced carcinogenesis. In place of the use of the person–rem concept, consideration should be given to expressing doses in terms of rem/person and comparing occupational or other man-made exposures to the 3 rem/30 year acquired from exposure to cosmic, terrestrial, and internal ^{40}K radiation, or the 10 rem/30 year if the National Council on Radiation Protection and Measurement (NCRP) Report No. 93 calculation including the radon contribution were valid. In this discussion, the term "rem" will be used to represent dose for low LET radiations which have been reported in rads, centigray, or rem.

Let us consider first what we know about the importance of dose–rate effects in radiation-induced malignancy for any given cumulative dose. It is important in such studies to distinguish between fractionated doses administered at high dose rates and continuous irradiation at low dose rates. There have been numerous animal studies demonstrating that the incidences both of leukemias and of solid tumors are markedly reduced when doses in the 100–300 rad range are delivered in days instead of in minutes.[3] The relevant human evidence depends in part on the use of ^{131}I for diagnosis of thyroid disease and for the treatment of hyperthyroidism. Although only a small fraction of the more than one million patients who had ^{131}I-uptake studies 20 or more years ago and received 50–100 rem thyroidal doses have been studied, no increase in thyroid cancer has been observed in this group.[4,5] Only 5% of the more than 35 000 patients evaluated were less than 20 at the time of examination. These authors concluded[4] that the carcinogenic potential of ^{131}I would be fourfold less than would result from equivalent externally administered x- or γ-ray exposure. Similarly, the absence of an increased incidence of leukemia following ^{131}I-treatment of hyperthyroidism, which generally delivers about 10 rem of generalized body radiation, is also consistent with a risk factor no more than one-fifth as great for radiation delivered over a period of days rather than seconds.[6,7] Perhaps the most critical evidence will become available in a very few years from observations on the evacuees following the Chernobyl accident. There was a group of ~25 000 people living between 3 and 15 km from the reactor who were reported to have had an average dose of about 50 rem. In addition, there was a cleanup crew of about the same size who received 50 rem or more.[8] These doses are comparable to the doses received by the survivors of the Hiroshima–Nagasaki bombings—but at a considerably lower dose rate. Will these survivors experience the same degree of leukemogenesis? We should soon know the answer since at comparable doses there was a doubling of leukemia incidence in the Japanese survivors during the 5–10 year period after the bombing.[1]

With the new Hiroshima–Nagasaki dosimetry there is a movement underway to reduce the NCRP and International Commission on Radiological Protection (ICRP) dose limits for occupational exposure below the current level of 5 rem/year. It would probably not be difficult or even expensive to comply with recommendations for setting lower limits. After all, according to the BEIR III report, in 1975, 96.5% of hospital-based radiation workers and 90% of industrial workers, including those working in reactor power plants or processing nuclear fuels, received less than 1 rem. Almost one-half of both groups received no measurable radiation. Nonetheless to lower the limits would suggest that there is some observable inherent risk at the current level and would raise great concern among radiation workers.

The picture of Marie Curie stirring large vats during the purification of radium will never of course be seen again. There is no doubt that early radiation workers had an increased incidence of aplastic anemia, leukemia, and bone cancer. As a result, by the 1920s radiation standards were initiated. What do we know about the extent of harmful effects among radiation workers exposed since the 1920s? A report in 1981 of the mortality from cancer and other causes among 1338 British radiologists who joined radiologic societies between 1897 and 1954 revealed that in those who entered the profession before 1921, the cancer death rate was 75% higher than that of other physicians. However those entering radiology after 1921 had cancer death rates quite comparable to those of other professionals.[9] Although the exposures of the radiologists were not measured, estimates suggest that those who entered the profession between 1920 and 1945 could have received accumulated whole-body doses during their working years as large as 100 to 500 rem.[9]

Another large group of radiation workers who have been studied were men in the Armed Services trained as radiology technicians during World War II and who subsequently served in that capacity for a median period of 24 months. Description of their daily training included the statement that "During the remaining two hours of this period the students occupy themselves by taking radiographs of each other in the positions taught them that day." [10] This report noted that the students did not receive a skin erythema dose nor did they show a drop in white count, monitoring procedures which are insensitive to acute doses less than 100 rem. From what we now know, these technicians probably received at least 50 rem or more during their training and several years of service. Yet a 29-year followup of these 6500 radiology technicians revealed no increase in malignancies when compared with a control group of similar size consisting of Armed Services medical, laboratory, or pharmacy technicians.[11]

Studies such as these suggest that the current maximum permissible dose levels could not be measurably deleterious. However to lower the limits suggests that the existing values are potentially harmful and contributes to radiation phobia in the general population and probably to law suits initiated by radiation workers who develop cancer.

In 1981 a Government Accounting Office Report on "Cancer risks of low-level ionizing radiation," concluded that "there is as yet no way to determine precisely the cancer risks of low-level ionizing radiation exposure, and it is unlikely that this question will be resolved soon." The question as to whether there exists a threshold below which radiation effects in man do not occur should continue to be addressed. One can develop a tenable model that would be consistent with such a threshold. Since human beings are more than

75% water, low-LET ionizing radiation is largely absorbed in the water resulting in the production of free radicals. Thus, many of the potential biochemical changes initiated in the cell and, in particular, damage to cellular DNA are probably a consequence of the action of the products of water radiolysis. If molecules which scavenge radicals and which are normally present in tissue greatly exceed in concentration the free radicals generated at low dose rates, there may well be no initiating event, i.e., damage to DNA. The threshold could be the dose rate at which the radiation-induced free radicals exceed the scavengers. It is likely to be dependent on the animal species and the specific tissue of concern. Such a hypothesis is consistent with the marked dose–rate effects observed in animal studies and is independent of other factors such as repair mechanisms that may also be operative to diminish damage.

The NCRP Report No. 43 dealing with "Radiation protection philosophy," stated unequivocally in 1975 that "The indications of a significant dose–rate influence on radiation effects would make completely inappropriate the current practice of summing of doses at all levels of dose and dose rate in the form of total person–rem for purposes of calculating risks to the population on the basis of extrapolation of risk estimates derived from data at high doses and dose rates... ." As medical physicists we should not only remember this statement but we should become actively involved in promoting this message to governmental agencies and to the society in which we live. If we fail to do so we are contributing to the radiation phobia which is based on the concept that any amount of ionizing radiation delivered at any rate is hazardous to human health. Such fears impact on the beneficial role of radiation in diagnosis and therapy, nuclear medicine, and nuclear power.

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[3]National Council on Radiation Protection and Measurements, "Tumorigenesis in experimental laboratory animals," NCRP Report No. 64, Washington, DC, 1980.

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