The Boice Report #33

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How Low Can You Go—Learning to Live With Uncertainty

As noted by Health Physics Society (HPS) Congressional Liaison David Connolly, one of the first bills passed by the House of Representatives this year was on low-dose radiation research! H.R. 5544 of 2014 morphed into H.R. 35 of 2015 with similar design: to develop a strategy for health research on low-dose radiation to meet national needs. But what is a "low dose of radiation" and can inherent uncertainties be addressed by more than educated guesses? Interestingly, the purpose of H.R. 35 mirrors that of ongoing National Council on Radiation Protection and Measurements (NCRP) Scientific Committee 1-21 (SC 1-21): to develop research recommendations on ways to enhance scientific understanding and reduce uncertainties with an aim to improve risk-management methods. Without question, predicting health risks of radiation exposure at low doses (<100 mGy) and low dose rates (<5 mGy h^{-1}) has significant uncertainties that are statistical and biological in nature. These uncertainties might be addressed by making fuller use of basic biology data coupled with high-quality and precise human epidemiologic data.

The Bill. H.R. 35 requires that (1) the scientific challenges to understanding low-dose effects be identified, (2) the current status of research be assessed, (3) the scientific goals for future research be formulated, (4) a long-term strategy be recommended, and (5) a research agenda be prioritized to overcome the challenges and meet the goals. H.R. 35 was received by the Senate on 8 January 2015 and referred to the Committee on Energy and Natural Resources. Contact your senator if you have an opinion on the value of this legislation. I certainly do and applaud our legislative leaders for recognizing a critical gap in the nation's infrastructure necessary to deal with the burgeoning exposure of the population to medical radiation, the potential burden of regulatory actions if overly conservative, as well as the consequences of nuclear terrorism (the latter not mentioned in the bill).

The Need. Why is such an evaluation so critically important? The United States, once the leader in all areas of radiation research, has apparently dismantled its radiation research infrastructure, has reduced its training opportunities, and has few radiation professionals today to meet national needs. This reduction in human capital is in contrast to the increasing uses of and population exposures to radiation and radioactive material. The Fukushima nuclear reactor accident and the ever-rising increase in population exposure to radiologic imaging examinations (computed tomography examinations, positron emission tomography scans, and nuclear medicine procedures) have increased the awareness of the importance of radiation protection guidance in the United States. With increased demand for oil and natural gas (see cover story in this newsletter), new technologies associated with hydraulic fracturing are being deployed in many states throughout the country, from Maryland to Wyoming. Application of this technology creates potential radiation exposures, environmental-protection concerns, and waste-management issues associated with technologically enhanced, naturally occurring radioactive materials (TENORM). Finally, the terrorist events in the world today, accentuated by the recent killing of innocent cartoonists at the Charlie Hebdo newspaper in Paris, should spur our efforts to counter nuclear terrorism and address emergency response and aftermath planning. The U.S. Congress has identified a critically important need for radiation understanding that directly affects every citizen in the United States!

The Uncertainty. How we know what we know or think we know and applying this knowledge is challenging in itself, but there are two additional hurdles to overcome in risk assessment: incomplete knowledge of low-dose radiation effects and the apparent randomness and inherent uncer-

tainty that may be a permanent feature of the world of low-dose radiation. The dilemma faced by risk assessors, risk predictors, and risk regulators is how to address our inability to observe human health effects at low doses of radiation. The uncertainties are statistical and biological and are so overwhelming that epidemiology (an observational, not an experimental, science) is incapable of detecting late-occurring health effects following low doses. Incomplete knowledge is related to the signal-to-noise-ratio problem. The tiny excess of cancer predicted from low doses of radiation (on the basis of high-dose interpolation) is too small to be convincingly observed against the very high background occurrence of cancer in the population; i.e., about 420 of every 1,000 people will develop cancer in their lifetime and if all 1,000 received an acute exposure of 1 mSv, less than 1 additional cancer case would be predicted (albeit with great uncertainty). Add to this inherent statistical uncertainty the biological uncertainties of what's happening at low doses and the possible differences in radiation response to low rather than high doses. Perhaps relevant is a recent widely publicized study (see HPS President Barbara Hamrick's message in this newsletter) that reported a strong correlation between lifetime risk of specific cancers and the number of lifetime cellular replications for the same specific tissues. The authors concluded that upwards of two-thirds of all cancers are not due to genetic predispositions or environmental factors but just bad luck during the normal cellular replication process! Such a possibility has been debated in the past, but raises the question as to the actual role that very low levels of environmental insults might play in the carcinogenic process. I'm not entirely convinced that reality can be determined by a probability curve, but it seems clear that the realm of radiation biology must be integrated with human epidemiology to have that quantum leap forward in understanding that will markedly change approaches to risk management.

NCRP SC 1-21 Committee. NCRP, with remarkable prescience (or coincidence), will soon publish a commentary on the health effects of low doses of radiation: integrating radiation biology and epidemiology. The goals are similar to those articulated in H.R. 35. Critical research needs for evaluation of low-dose radiation health effects will be the focus. Bridging the gap from molecules to epidemiology might benefit from the "key-event" approach and biologically based models used in conjunction with high-quality radiation epidemiology data to reduce overall uncertainty in low-dose risk estimates and management. The high-quality, large-scale, epidemiologic data might come from the Million U.S. Worker and Veteran Study.

NCRP Scientific Committee 1-21 on Low-Dose Radiation: Integrating Biology and Epidemiology, October 2014, Bethesda, Maryland

Front row, left to right, Sally Amundson (chair, Columbia University Medical Center), John D. Boice, Jr. (president, NCRP), and William Morgan (Pacific Northwest National Laboratory)
Back row, left to right, Jonine Bernstein (cochair, Memorial Sloan-Kettering Cancer Center), Mark Little (National Cancer Institute), Amy Kronenberg (Lawrence Berkeley National Laboratory), Julian Preston (U.S. Environmental Protection Agency, retired), Simon Powell (Memorial Sloan-Kettering Cancer Center), Jac Nickoloff (Colorado State University), and Marvin Rosenstein (NCRP staff consultant)
Not in main photo, top to bottom, Keith Eckerman (Oak Ridge National Laboratory), Ray Guilmette (Los Alamos National Laboratory, retired), and Dan Stram (University of Southern California)

The NCRP annual meeting is 16–17 March 2015. Don't forget to register for "Changing Regulations and Radiation Guidance—What Does the Future Hold?" (it is free). You may discover how regulations and risk management strategies are being approached in a world full of uncertainty!