

**MEETING SUMMARY
PRESIDENT'S CANCER PANEL
ENVIRONMENTAL FACTORS IN CANCER**

January 27, 2009
Phoenix, Arizona

OVERVIEW

This meeting was the last in the President's Cancer Panel's (PCP, the Panel) 2008/2009 series, *Environmental Factors in Cancer*. The meeting focused on radiation exposures as they relate to cancer risk. The agenda for the meeting was organized into three discussion panels.

PARTICIPANTS

President's Cancer Panel

LaSalle D. Leffall, Jr., M.D., F.A.C.S., Chair
Margaret Kripke, Ph.D.

National Cancer Institute (NCI), National Institutes of Health (NIH)

Abby Sandler, Ph.D., Executive Secretary, PCP, NCI
Beverly Laird, Ph.D., Vice-Chair, Director's Consumer Liaison Group

Panelists

David J. Brenner, Ph.D., D.Sc., Director and Higgins Professor of Radiation Biophysics, Center for Radiological Research, Columbia University Medical Center
David O. Carpenter, M.D., Director, Institute for Health and Environment, University at Albany School of Public Health
Thomas H. Essig, M.S., Rehired Annuitant, Office of Federal and State Materials and Environmental Management Programs, U.S. Nuclear Regulatory Commission (NRC)
Michael Lerner, Ph.D., President and Founder, Commonweal
Martha S. Linet, M.D., M.P.H., Chief and Senior Investigator, Radiation Epidemiology Branch, National Cancer Institute
Mahadevappa Mahesh, Ph.D., M.S., Associate Professor of Radiology and Cardiology, Johns Hopkins University School of Medicine
Fred A. Mettler, M.D., M.P.H., Professor Emeritus, Department of Radiology, New Mexico VA Healthcare System
Neal A. Palafox, M.D., M.P.H., Professor and Chair, Family Medicine and Community Health, John A. Burns School of Medicine, University of Hawai'i at Manoa
Trisha Thompson Pritikin, Esq., M.Ed., Hanford Downwinder, Berkeley, CA
Jonathan Samet, M.D., M.S., Professor and Chair, Department of Preventive Medicine, University of Southern California (USC)/Norris Comprehensive Cancer Center
William A. Suk, Ph.D., M.P.H., Acting Deputy Director, National Institute of Environmental Health Sciences

OPENING REMARKS—LaSALLE D. LEFFALL, JR., M.D., F.A.C.S.

On behalf of the Panel, Dr. Leffall welcomed invited participants and the public to the meeting. He introduced the Panel members, provided a brief overview of the history and purpose of the Panel, and described the aims of the current series of meetings.

PANEL I

DR. JONATHAN SAMET:

RADIATION AND CANCER RISK: MORE EPIDEMIOLOGICAL RESEARCH IS NEEDED

Background

Dr. Samet, a pulmonary physician and epidemiologist, is currently Professor and Flora L. Thornton Chair for the Department of Preventive Medicine at the Keck School of Medicine at USC and Director for the USC Institute for Global Health. His research has focused on the health risks of inhaled pollutants – particles and ozone in outdoor air and indoor pollutants including secondhand smoke and radon. Dr. Samet has also investigated the occurrence and causes of cancer and respiratory diseases, emphasizing the risks of active and passive smoking.

Key Points

- Evidence-based radiation protection relies on epidemiologic and laboratory research. Epidemiology provides information about the population-level risks of radiation exposure. Laboratory research helps elucidate the mechanisms by which radiation contributes to cancer and other diseases.
- This evidence-based radiation protection paradigm was used to establish the adverse health effects of radon. An estimate of the number of lung cancer deaths due to radon was generated based on epidemiological data from 11 cohorts of uranium miners, as well as data from a number of mechanistic studies conducted in the laboratory. This analysis has been used worldwide as a basis for establishing guidelines and standards for acceptable levels of indoor radon in homes.
- Epidemiological and laboratory research have informed the development of dose-response models and have sometimes spurred quantitative risk assessments (QRAs), both of which contribute to the development of policy. The four main elements of a radiation QRA include hazard identification, dose-response relationship, exposure assessment, and risk characterization.
- The most recent BEIR Report – BEIR VII: “Health Risks from Exposure to Low Levels of Ionizing Radiation” – acknowledges the substantial evidence that exposure to high levels of ionizing radiation can cause illness and/or death. However, significantly less data are available for low levels of exposure to radiation, making it more difficult to develop models that accurately assess risk.
- The effects of low-dose radiation could have important regulatory implication; thus, additional research is needed to fill knowledge gaps in this area. The BEIR-VII Report lists several specific areas in which research is needed, including genetic factors that influence cancer risk and the genetic effects of radiation therapy used in treatment of childhood cancers. To facilitate this research, radiation worker registries and cohorts of people exposed to medical radiation should be established and existing cohorts maintained. Biological materials archived in Hiroshima could be used to understand genetics and biomarkers related to risk.

- Quantitative risk estimates for radiation exposure should be strengthened using additional data as it is generated. Risk estimates and models must take into account the changing patterns of exposure (e.g., increased use of medical radiation, younger ages of exposure to medical usage). Surveillance of radiation risks in populations must be maintained to enable analysis of unexpected events (e.g., thyroid cancer in children following Chernobyl). Large population studies, national databases for record linkage, and increased understanding of genetic determinants of susceptibility are all needed to improve the accuracy of risk estimates.
- Some of the groups who conduct epidemiological research on radon and cancer include the NCI Radiation Epidemiology Branch, the Radiation Group of the International Agency for Research on Cancer, the Radiation Effects Research Foundation, and the Radiation Protection Bureau of Health Canada.

DR. MARTHA LINET:

CELLULAR (MOBILE) TELEPHONE USE AND CANCER RISK

Background

Dr. Linet has served as Chief of the Radiation Epidemiology Branch of the National Cancer Institute since 2004. She has been a Senior Investigator at NCI since 1987 and was previously Associate Professor in the Department of Epidemiology at the Johns Hopkins School of Public Health. Dr. Linet conducts research on cancer incidence and mortality among radiologic technologists. She also studies risk factors for childhood and adult hematopoietic malignancies, including the role of nonionizing radiation exposures from power lines and electrical appliances in relation to childhood leukemia and cellular telephone use in relation to adult brain tumors.

Key Points

- Exposure to nonionizing radiation – which includes near ultraviolet and visible light as well as infrared, microwave, radio frequency (RF), and extremely low-frequency radiation – is ubiquitous and, consequently, a topic of polarized public health commentary. Ionizing radiation sources (e.g., gamma rays, x-rays), which constitute the shorter wavelengths of the electromagnetic spectrum, are known to be carcinogenic, but the carcinogenicity of longer wavelength, nonionizing sources (e.g., cell phones, televisions, power lines) remains unknown.
- Many people, including members of the general public and regulators, have become concerned about RF radiation exposure due to cell phone usage and whether this exposure increases the risk of brain cancer. Cell phone use began in the U.S. in the 1980s, but remained low until 2000, when mobile phones switched from an analog to a digital signal. In 2007, there were 255 million cell phone subscribers in the United States. The number of users continues to rapidly rise, yet the biological effects associated with RF radiation remain unclear.
- The NCI Surveillance, Epidemiology, and End Results (SEER) Program tracked trends in brain cancer incidence by age from 1973 to 2005. The highest incidence of brain tumors was in middle-aged individuals (45-64 year olds) and the elderly (65 years or older). There have been some increases in brain cancer incidence among the elderly over this time period; these are thought to be primarily due to increased use of imaging equipment for diagnosis and detection of cancer (e.g., computed tomography [CT] scans, and magnetic resonance imaging [MRI]).

- Early studies of the health effects of cell phones were launched by NCI, the American Health Foundation, Örebro University in Sweden, and the Danish Cancer Society in 1994. These studies focused on brain tumors, particularly gliomas, meningiomas, and acoustic neuromas. Results from these four studies were reported in 1999 to 2001. The studies found no evidence of association of cell phone use and risk of developing adult gliomas in terms of minutes per day/hours per month of use, duration in years of use, and cumulative lifetime hours of use. Three of the four studies found no evidence of excess tumor occurrence on the same side of the head as cell phone use.
- Results from these three studies were consistent but had a number of limitations. First, cases were diagnosed in the 1990s, before the switch from analog to digital frequencies and the associated rapid increase in use. Second, exposure was assessed through the use of questionnaires, a research method that is associated with a number of limitations, including recall bias and impaired memory of participants. Lastly, these studies were limited by a lack of cases with high frequency and duration of cell phone use.
- The next generation of cell-phone-use studies included the Expanded Danish Cohort Study and the INTERPHONE Consortium of Case-Control Studies. The Expanded Danish Cohort Study involved follow-up of 420,095 persons with first cell phone subscriptions between 1982 and 1995. The study compared cancer incidence of this cohort with that of the general population and found no increase in brain tumor incidence among long-term cell phone subscribers.
- The INTERPHONE Study of Brain & Other Tumors was led by the International Agency for Research on Cancer (IARC) and used population-based registries in 13 different countries. The participating countries had earlier adoption of cell phone technology than the U.S. and the range of cases studied was diagnosed during 2000-2004. Full results have not yet been reported, but there are results of pooled analyses from five countries (Denmark, Finland, Norway, Sweden, and the United Kingdom) available.
- In the pooled analyses of glioma – which included 1,521 glioma patients and 3,301 controls – there was no overall increase in risk associated with years since first use, lifetime years of use, number of calls, hours of use, or use of analog versus digital phones. There was a slight increase in risk of brain tumors arising on the same side of the head for long-duration (10 or more years) users.
- In the pooled analyses of meningioma – which included 1,209 meningioma cases and 3,299 controls – there was no overall increase in risk associated with years since first use, lifetime years of use, number of calls, hours of use, or use of analog versus digital phones. There was no association for occurrence of tumors on same side of the head as cell phone use.
- In the pooled analyses of acoustic neuroma – which included 678 acoustic neuroma cases and 3,553 controls – there was no overall increase in risk associated with years since first use, lifetime years of use, number of calls, hours of use, or use of analog versus digital. There was an increased risk of brain tumors arising on the same side of the head for long-duration (10 or more years) users.
- An occupational study of 195,775 Motorola workers employed for at least 6 months in 1976-1996 focused on RF exposure in the manufacturing of cell phones. The RF exposures were estimated by specific exposures associated with a job title (personal cell phone use was not taken into account). The study results found no association between occupational RF exposure and mortality due to brain cancer.
- Another relevant study involved 49,581 U.S. Navy veterans of the Korean War who had potential exposure to high-intensity radar. There was no evidence of increased mortality within this group due to brain cancer.

- An urgent issue that needs to be addressed is whether children and adolescents using cell phones are at increased risk for brain tumors. Studies of ionizing radiation have shown that children are more sensitive than adults to carcinogenic exposures, and differences in sensitivities may exist for RF radiation as well. There are no published epidemiologic studies of cell phone use during childhood and subsequent cancer risk. However, there are ongoing case-control studies being carried out in Denmark, Norway, Sweden, and Switzerland, as well as ongoing Danish and Norwegian childhood cohort studies.

DR. WILLIAM SUK:

ENVIRONMENTAL FACTORS IN CANCER

Background

Dr. Suk is currently Acting Deputy Director of the National Institute of Environmental Health Sciences (NIEHS). He has served in a number of leadership positions at NIEHS. A primary aspect of these positions is assessment of current biomedical research and its potential applications in determining adverse effects on human health resulting from exposure to deleterious environmental agents. Dr. Suk has worked extensively with the biomedical science research communities; he has a comprehensive knowledge of public health policy and an in-depth understanding of technology and information translation, nationally and internationally.

Key Points

- Environmental health researchers are being challenged to focus on a broader array of exposures and develop a better understanding of the continuum from exposure to disease outcome. The linkages between multiple exposures and disease are important to improve risk assessment and epidemiology studies as well as to increase the utility of exposure information in clinical settings. In addition to toxicity, the route and length of exposure, genetic polymorphisms, age of an individual, and exposures to other substances will determine whether an exposure will lead to disease.
- In collaboration with the National Human Genome Research Institute, NCI, and other NIH Institutes and Centers, NIEHS has developed a program devoted to exposure sciences, which specifically looks at biological responses following exposure to a particular substance. Understanding molecular mechanisms of exposure and disease is necessary to be able to reduce exposures and develop a scientific basis for risk comparison.
- Inherited single-gene mutations are the major cause of cancer and cardiovascular disease in less than 5 percent of cases. Seventy to 90 percent of major diseases in the U.S. are caused by reversible and/or avoidable behaviors and exposures.
- Understanding exposures and disease outcomes will require increased knowledge of exposure-gene interactions. This necessitates a thorough understanding of genetics and susceptibility factors and the ability to extrapolate data from animal models to humans. Understanding the genetics of disease resistance is also important and should not be overlooked.
- The linkages between environmental exposures and genotypes are complex; thus, a systems biology – or systems toxicology – approach that fosters interdisciplinary study is needed to address them. One approach is the relatively new field called toxicogenomics, which capitalizes on the ability to examine all the genes in the genome simultaneously in order to analyze an organism's response to an environmental exposure. These types of studies can shed light on the signaling pathways and networks that are relevant to disease outcomes. Computational biology – an interdisciplinary field that combines techniques of computer

science, applied mathematics, and statistics – can also be applied to interpret results of research on exposure to one or more environmental agents. Different algorithms can be associated with a particular exposure(s) (e.g., radiation) to assess risk.

- Children, approximately 40 percent of the world's population, are the most vulnerable to harmful environmental exposures. Pound for pound of body weight, children have disproportionately heavy exposures to environmental factors. Children's metabolic pathways are immature, and their developmental processes are easily disrupted. Adverse health effects in early stages of life affect health in the later stages, and sometimes even health of the next generation. Early-life exposures are shown to have an effect on heart disease, cancer, asthma, and other diseases in adulthood.
- Protecting children from harmful environmental exposures is a global challenge. Coordinated local and global data collection on environmental exposures in children is needed, as is a global epidemiological effort to fill gaps in the understanding of the relationship between environmental exposures and ill health in children. Such an effort has been launched by the National Institute of Child Health and Human Development in cooperation with the Environmental Protection Agency, NIEHS, and others. The National Children's Study is assessing children from across the U.S. for a variety of exposures and disease outcomes, and different types of radiation exposures should be included.

MR. THOMAS ESSIG:

ROLE OF THE NRC IN THE CONTROL OF OCCUPATIONAL AND ENVIRONMENTAL RADIATION EXPOSURE

Background

Mr. Essig currently provides consulting services in health physics and emergency preparedness through HP&EP Technology Management, LLC, for which he serves as Principal. In November 2006, he retired from employment with the U.S. Nuclear Regulatory Commission. While at the NRC, Mr. Essig provided direction and leadership to health physics, emergency preparedness, materials licensing, waste management, and environmental protection programs as well as incident response activities. He also served as a reactor licensing reviewer and reactor health physics inspector. Mr. Essig also managed research and development programs in the areas of health physics and emergency preparedness while employed by the U.S. Department of Energy's Pacific Northwest National Laboratory. Mr. Essig has a B.S. in applied (engineering) physics with special emphasis on nuclear engineering from Michigan Technological University. He received an M.S. in environmental engineering with special emphasis on radiological health from Washington State University. Mr. Essig has been certified in the comprehensive practice of health physics by the American Board of Health Physics.

Key Points

- Commercial use of radioactive material was facilitated by the Atomic Energy Act of 1954. At that time, the Atomic Energy Commission was charged with both the development and regulation of nuclear activities. In the mid-1970s, Congress decided to separate nuclear development and regulatory activities. The Atomic Energy Commission was split into the NRC, which was charged with regulation of atomic energy, and the Energy Research and Development Administration, which undertook nuclear development activities and eventually became the Department of Energy.
- At the time of its creation in 1975, NRC was given authority to license nuclear power plants and other fuel cycle facilities and regulate uses of byproduct material, source material, and other special nuclear material. The Energy Policy Act of 2005 extended the authority of NRC

to include regulation of discrete sources of radium-226 as well as radioactive materials produced by particle accelerators; NRC does not have authority to regulate diffuse sources of radium or the operation of accelerators.

- The NRC regulatory program establishes standards and regulations, issues licenses for nuclear facilities and users of radioactive materials, inspects licensed activities, and undertakes enforcement action when programs are not in compliance.
- The U.S. population is exposed to both natural and man-made sources of ionizing radiation. NRC regulates a subset of the man-made sources, including consumer products and nuclear power. These account for a relatively small portion of radiation exposure. NRC, along with its Agreement States, licenses and regulates the possession and use of radioactive materials for nuclear medicine. The goals of these regulations are to protect authorized users (e.g., technicians, health professionals) and the general public. NRC does not regulate the radiation exposure obtained by patients undergoing diagnostic or therapeutic medical procedures with licensed materials. Medical licensees (individuals who use radioactivity for medical purposes) are required by the NRC to implement quality management programs to ensure treatment is delivered as prescribed. There are also regulations regarding reporting of unexpected/unplanned doses to organs/tissues as well as regulations pertaining to patients who are administered a radioactive material for an exam. These patients cannot be released until exposure levels of individuals around them are less than 5 millisieverts (mSv).
- When establishing its regulations, NRC uses the linear no-threshold (LNT) hypothesis for radiation exposure and its effects; thus, NRC endorses the principle of maintaining exposures as low as reasonably achievable. Risk estimates in the BEIR VII Report indicate that NRC standards for radiation exposure help ensure that risk of fatal cancer to the public from NRC-licensed activities is less than 0.01 percent.
- Radiation protection standards for workers and the public are set forth in 10 CFR Part 20. Other regulations focus on specific practices or facilities, such as nuclear power plants and medical applications.
- NRC issues two types of licenses: specific and general. Specific licenses are issued to a person or corporate entity and authorize use of certain radioactive materials in a particular manner. Review and issuance of specific licenses are handled by NRC and the 35 participants in its Agreement State Program. Agreement States are given authority to issue licenses, perform inspections, and take enforcement action for most licensee categories (with the exception of fuel cycle facilities such as nuclear power plants). Approximately 17,000 specific licensees are under jurisdiction of the Agreement States and about 4,500 are under NRC jurisdiction. General licenses are authorizations contained in regulations and are limited to certain devices such as industrial gauges.
- All specific licensees are inspected on a regular basis to ensure that regulation requirements as well as license conditions and orders are met. Inspections focus on a sample of work being done by the licensee; if problems are found or suspected, the area is more closely examined. Inspection frequency varies depending on the nature of the licensed activity. For example, nuclear power plants have resident inspectors while other program inspections occur annually or only once every several years.
- If serious questions arise about the safety of licensed activities, these activities may be stopped by the NRC or an individual may be prohibited from working with the licensed material. NRC may modify, suspend, or revoke a license at any time, and work activities may not resume until the identified problems are resolved. NRC also has the authority to issue civil penalties.

- Certain items are exempt from licensing under the Atomic Energy Act. These include tritium in watch dials, americium-241 in smoke detectors, and certain internal sources for radiation-measuring instruments. Other exemptions are provided for small quantities or concentrations of radioactive material, such as those in radiation detector check sources.
- The NRC has a research program that provides independent information and expertise to assist in making safety and security decisions. Examples of research activities include the long-term strength of nuclear reactor components, radioactive waste transport and disposal, technical bases for NRC Regulatory Guides, and the impact of changes to radiation dose limits.
- NCI conducted a major study from 1987 to 1990 regarding cancer mortality in 52 areas containing nuclear power plants, 9 Department of Energy (DOE) facilities, and a commercial spent-fuel reprocessing plant. Some of the exposed counties exhibited higher rates of cancer than control counties, but some exposed counties actually had lower cancer rates. Within the statistical power of the study, none of the observed differences could be linked with the presence of the nuclear facilities.
- The NRC concurs with the research needs outlined by the National Research Council in the BEIR VII Report. These include the study of molecular markers of DNA damage and repair fidelity, mechanisms of carcinogenesis, genetic factors affecting cancer risk, occupational and environmental studies, and fallout reviews of Japanese atomic bomb survivors. NRC is specifically interested in studies that address the adequacy of or highlight necessary changes to existing radiation protection standards for radiation workers, the general public, and the environment.
- NRC regulations have evolved over several decades, largely based on recommendations from the International Commission on Radiological Protection. As a result, the regulations contain a variety of dose limits, constraints, design objectives, and dose-based criteria. Although safety has been adequately protected, some inconsistencies have been created, which may affect the competitiveness of U.S. industries in the international marketplace. The NRC is working with the Interagency Steering Committee on Radiation Standards to address some of these issues.
- The terrorist attacks of September 11, 2001 prompted changes to the way radioactive material is secured. In 2004, the International Atomic Energy Agency (IAEA) published the *Code of Conduct on the Safety and Security of Radioactive Sources*, which provides a framework for simultaneous consideration of source safety and security issues. All IAEA member states, including the United States, have agreed to implement the provisions of this document to at least some extent. However, care must be taken not to sacrifice security by zealously pursuing safety issues, or vice versa. For example, additional locks and barriers may increase security by decreasing source accessibility; however, these security features could inhibit routine maintenance activities, potentially increasing occupational doses. Another issue under discussion could affect the sterilization of blood for use in the health care system; this is currently done using cesium-137 irradiators, but there are concerns that the properties of cesium (e.g., solubility in water) make it attractive for terrorist use. Discontinuation of the use of cesium sources without the development of alternative sterilization methods could detrimentally affect the blood supply.

DISCUSSION:

PANEL I

- Emphasis needs to be placed on developing surveillance mechanisms and early warning systems that can track changing patterns of exposure (e.g., increased cell phone use) and predict associated risks.
- Current study data fail to show a correlation between increased use of cell phones and brain cancer incidence; however, there may be a long latency period for disease onset, and it may be that insufficient time has passed to see the full effects of cell phone use. This was the case for lung cancer in underground uranium miners; there was a minimum of 20 years following first exposure before excess risk manifested in the form of solid tumors.
- Considering all the confounding influences from multiple genes, genetic susceptibilities, and exposures, it is going to be increasingly difficult to identify one-to-one linkages between exposure and disease.
- There are statistical tools available to look at the health consequences of several environmental exposures simultaneously, but the quantity of data needed for robust analysis escalates significantly as the number of exposures being assessed increases. Epidemiologists recognize that large populations with variation in exposure and nonexposure are needed; consortia are being formed all over the world to carry out pooled studies. Efforts are also being undertaken to standardize the strategy for analyzing data from these pooled studies.
- An important paper on gene-exposure relationship was published in *PLoS Genetics* in November 2008. Dr. Leona Samson and colleagues at the Massachusetts Institute of Technology identified five to seven genes that were expressed as a result of high levels of arsenic exposure.
- An example of an internal source of radiation is the naturally occurring potassium-40 that is present in all animal tissues.
- The accuracy of extrapolating data from animal models to humans varies with the type of exposure, disease, and tumor. Many animal studies have been conducted in rodents, but there is now a trend toward using organisms such as nematodes and fruit flies. Although these less advanced organisms provide opportunity for high-throughput studies, extrapolation of data from these models will be even more challenging.
- The NRC only regulates discrete sources of Radium-226, because those sources have been refined and encapsulated and would be more attractive to someone trying to do societal harm (e.g., terrorists). Other sources of radium require more preparation and refinement to produce a form that could cause great harm.
- A pipeline of population researchers with multidisciplinary training needs to be sustained. The NIH already provides training at the graduate, predoctoral, and postdoctoral levels, but should develop a health-/biomedical-related training program for use at the K-12 level.

PANEL II

DR. DAVID BRENNER:

SHOULD WE BE CONCERNED ABOUT THE RAPID INCREASE IN COMPUTED TOMOGRAPHY USAGE?

Background

Dr. David Brenner is Higgins Professor of Radiation Biophysics at Columbia University, Director of the Center for Radiological Research at Columbia University, Director of the Columbia University Radiological Research Accelerator Facility (RARAF), and Principal Investigator of the Center for High-Throughput Minimally Invasive Radiation Biodosimetry. His research focuses on developing mechanistic models for the effects of ionizing radiation on living systems, both at the chromosomal and the animal levels.

Key Points

- Computed tomography has transformed medical imaging by providing three-dimensional views of the organ or body part of interest. Many radiographic images are taken as the CT machine rotates and moves around a patient, and these are combined by computer to produce a 3D image. Compared to conventional radiological examinations (e.g., chest x-ray, mammogram), CT produces a larger x-ray radiation dose. For example, the average x-ray radiation dose to the lung from a chest CT is about 100 times more than that from a conventional chest x-ray.
- CT scanner usage has rapidly increased since the technology was introduced in 1973. Currently, about 70 million CT scans per year are being performed in the U.S.
- Typically, when a patient receives a CT exam, more than one scan is performed. About one-third of patients who have CT exams have at least three scans. For example, the average number of CT scans delivered to trauma patients in their initial evaluation is three.
- Reasonable estimates of the number of pediatric CT scans performed per year in the U.S. were 0.5 million in 1989 and 5 million in 2007. Of those 5 million CT scans, three-quarters were performed on children under the age of 5.
- Pediatric CT is qualitatively different from adult CT. Organ radiation doses can be much larger for children than for adults. Children are also much more sensitive to radiation-induced cancer than adults. There is a long latency period between radiation exposure and the onset of a radiation-induced cancer – an exposed child has more time for a cancer to develop than an individual exposed in old age.
- There is considerable variation in CT radiation doses from institution to institution. An FDA study conducted in 2000 compared dosage from the same CT examination performed at 100 different institutions. The relevant organ dose range was found to be 5 to 100 mSv, reflecting a greater than 10-fold difference in dose between institutions. This is a quality control issue that needs to be corrected.
- Some Hiroshima and Nagasaki atomic bomb survivors were exposed to a similar radiation dose as individuals who undergo a CT scan. At the epicenter of the bombed area, radiation doses were extremely high, but the dose decreased as distance from the epicenter increased. Individuals 2,000 to 3,000 yards away from the epicenter were typically exposed to 5 to 100 mSv of radiation.

- There is epidemiological evidence for an increase in cancer risk upon exposure to radiation at levels equivalent to those received during a CT scan. About 28,000 atomic bomb survivors who received radiation doses in the 5 to 100 mSv dose range were studied for cancer incidence from 1958 to 1998. Of the 4,406 solid tumors observed in this population, 81 were estimated to be radiation-related cancers. This small, but statistically significant, radiation-associated increase in cancer risk provides direct evidence that radiation doses similar to those experienced during a CT scan are associated with an increase in cancer risk.
- CT usage is likely to significantly increase in the next decade. Until recently, CT was predominantly used for diagnosing disease; however, there is increasing interest in its use for screening apparently healthy individuals. The risk-benefit balance of CT is very different for screening compared to diagnosis. At least four types of CT-based screening are becoming increasingly common: lung cancer screening in current and former smokers; cardiac disease screening; colon cancer screening (i.e., “virtual colonoscopy”); and whole-body CT screening.
- Because of the long latency period associated with radiation-induced cancer, it is now reasonable to initiate epidemiological studies of cancer risk resulting from CT scans. In 2008, the UK-NCI Pediatric CT Study of Cancer Risk was initiated. Using the UK’s centralized record-keeping system, data on 200,000 patients receiving CT scans will be collected.
- Individual lifetime cancer risk associated with CT is small; for example, the lifetime cancer risk estimate associated with an abdominal CT scan of a 25-year-old is 0.05 percent, or 1 in 2,000. The potential benefit of the CT scan will likely far outweigh this individual risk. While individual risk estimates for CT are small, concern arises from the rapid increase in CT usage. Small individual risks applied to an increasingly large population – 5 million children and 65 million adults – may result in a major public health issue.
- In order to avoid such a public health dilemma, CT usage and doses must be reduced without compromising patient care. This can be done through reducing the dose per scan that a patient receives, minimizing unnecessary imaging, and using other imaging modalities (e.g., ultrasound or MRI) when possible.
- Recently, a new generation of CT scanners has been developed that feature automated tube current modulation, in which the machine assesses the shape of the individual being scanned and determines the minimum amount of radiation needed to produce an acceptable image.
- It is estimated that one-third of all CT scans could be replaced by an alternative approach or not be performed at all. However, targeting this subset of scans is a difficult task, in part because physicians are subject to numerous pressures – including legal, economic, and from patients themselves – to perform CT scans. Also, CT scans are often the quickest way to obtain information about key organs when a patient is brought to the emergency room.
- The only likely way to address these pressures is through widespread acceptance and use of clinical decision rules (i.e., evidence-based imaging protocols for most common scenarios). For example, it is unusual for a child to receive an appendectomy without a CT scan to confirm appendicitis; however, decision rules could reduce the proportion of children receiving a CT before appendectomy by as much as 50 percent while still maintaining diagnostic efficiency.
- A study on the potential impact of decision rules was recently published in the *American Journal of Roentgenology*. Data from 200 trauma patients who had some form of radiation imaging were analyzed. Of these patients, 169 had a total of 660 CT scans, which cost a total of \$837,000. Had the decision rules been followed, 44 percent of the scans would not have been performed; none of the major injuries diagnosed would have been excluded from CT imaging; and there would have been a 39 percent decrease in cost.

DR. FRED METTLER:

MEDICAL RADIATION EXPOSURE: HOW MUCH, WHY, AND SO WHAT?

Background

Dr. Fred Mettler is currently Professor Emeritus of the Department of Radiology at the University of New Mexico School of Medicine. He is also Chief of Radiology and Nuclear Medicine at the New Mexico Federal Regional Medical Center. Dr. Mettler is also the United States Representative to the United Nations Scientific Committee on the Effects of Atomic Radiation and Emeritus Commissioner of the International Commission on Radiation Protection. He has served as an expert on radiation effects and accidents for the U.S. Peace Corps, Centers for Disease Control and Prevention (CDC), World Health Organization, International Atomic Energy Agency, International Agency for Research on Cancer, and the Japanese, Costa Rican, Peruvian, Panamanian, and Polish governments.

Key Points

- There are three general categories of medical exposure to ionizing radiation: diagnostic radiology, nuclear medicine, and radiation therapy. Diagnostic radiology refers to images obtained using x-rays (e.g., chest x-ray, mammogram, CT). Nuclear medicine refers to the introduction of unsealed radioactive materials into the body to obtain images or treat medical conditions. Radiation therapy is the use of ionizing radiation to treat various diseases, usually cancer.
- Medicine is the largest controllable source of radiation exposure, but it remains essentially unregulated. Medical radiation exposure has increased 600 to 700 percent over the past 20 years.
- Many radiology departments are now completely digital and no longer use film. The convenience of instantaneous images and reports means more usage; however, digital radiography generally results in higher doses of radiation to the target organ than film radiography.
- In 2006, there were an estimated 410 million diagnostic and interventional radiology examinations and 20 million nuclear medicine examinations in the U.S. The U.S. has approximately 4.6 percent of the world's population and accounts for about 25 percent of all diagnostic x-ray examinations and about one-half of all nuclear medicine procedures done in the world.
- Recent advances in machine technology have led to more applications and markedly increased usage of medical radiation. The frequency of diagnostic radiology and nuclear medicine examinations has increased 10- to 15-fold between 1950 and 2006. New CT scanners can take hundreds of images in less than 0.3 seconds, allowing application to many more diagnostic problems.
- The major change in nuclear medicine has been the marked increase in cardiac procedures, which has been attributed to self-referral by cardiologists. In the 1980s, cardiologists rarely performed nuclear medicine themselves, but now at least two-thirds of these procedures are performed by cardiologists. Cardiac procedures account for almost 60 percent of the total number and over 85 percent of the collective effective dose from all diagnostic nuclear medicine procedures.
- Increases in medical radiation usage can also be attributed to CT manufacturers who advertise scanners directly to self-referring clinicians. Lawyers have started to focus on manufacturers in regard to design defects and failure to warn patients about a risk of cancer.

- Also alarming is the fact that gift certificates are available for CT scans.
- In the U.S., the annual collective radiation dose due to medical exposure is about 900,000 person-sieverts (person-Sv). Estimates generated using a linear-no-threshold calculation indicate that 50,000 to 60,000 fatal cases of cancer annually may be due to x-ray procedures. The linear-no threshold model presupposes that the damage caused by ionizing radiation is linear (i.e., directly proportional to the dose), even at low levels of exposure.
- Sixty million CT scans and over 20 million nuclear medicine scans done annually in the U.S. may cause up to 40,000 fatal cancers annually in the next one to three decades.
- There is a misconception that because patients exposed to medical radiation are often elderly, radiation risk is overestimated. However, in the U.S., less than 5 percent of radiological examinations are performed in the year prior to death.
- Unfortunately, it is not possible to merely reduce the amount of radiation used in a medical procedure in order to reduce risk. Too little radiation can undermine both diagnostic and treatment applications. The challenge is to provide a sufficient dose for diagnosis or screening without exposing the patient to excessive radiation.
- In order to avoid unnecessary medical radiation exposure, patients must be advocates for themselves. Patients should also make sure to get a copy of their digital radiation images on CD to avoid unnecessary replication of procedures.

DR. MAHADEVAPPA MAHESH:

MEDICAL RADIATION EXPOSURE WITH FOCUS ON CT DOSE

Background

Dr. Mahadevappa Mahesh is Associate Professor of Radiology and Associate Professor of Medicine in the Johns Hopkins University School of Medicine Division of Cardiology and Chief Physicist at Johns Hopkins Hospital. His research interests are in medical imaging, particularly in the areas of multidetector computed tomography (MDCT), interventional fluoroscopy, and digital mammography. Current research includes patient dose evaluation during MDCT, radiation dose measurement, and optimization of clinical protocols in MDCT. Dr. Mahesh is certified by the American Board of Radiology in diagnostic radiological physics and is a member of the Radiation Control Advisory Board for the State of Maryland. He was elected a Fellow of the American Association of Physicists in Medicine and is a member of Scientific Committee (SC 6-2) of the National Council of Radiation Protection and Measurements. Dr. Mahesh is also active in the American College of Radiology, the Radiological Society of North America, and the Health Physics Society.

Key Points

- The National Council on Radiation Protection and Measurements (NCRP) formed a scientific committee (SC 6-2) to investigate the medical radiation exposure of the U.S. population. The committee found that approximately 384 million radiological imaging procedures were performed in 2006, resulting in an annual collective effective dose of 900,000 person-sieverts (person-Sv).
- In 1982, the last year for which the NCRP assessed radiation exposure of the U.S. population, the effective radiation dose from medical procedures was 0.54 mSv per capita, accounting for only 15 percent of total radiation exposure (83% of radiation exposure was from natural sources). In 2006, however, medical radiation exposure had risen to approximately 3.0 mSv per capita, a level virtually equal to exposure from natural sources.

- Probable causes for the observed increases in medical radiation exposure include advances in medical technology, demand for improved patient care, and the ease of use and increased availability of medical imaging modalities.
- The NCRP committee found that the largest contributions to medical radiation exposure were from CT scanning and nuclear medicine. Together, these procedures account for only 22 percent of radiological imaging procedures; however, they impose 75 percent of the medical radiation dose.
- Between 1993 and 2008, the number of CT procedures increased more than 10 percent per year on average, compared to a population increase of less than 1 percent per year. The most dramatic increase in CT scans occurred following the introduction of MDCT in U.S. hospitals in around 1998. Although MDCT has many medical advantages, its availability has also contributed to the increase in the number of medical imaging procedures being conducted.
- Nearly 80 percent of CT scans performed in the U.S. are of the head, chest, neck, or pelvis; these account for 84 percent of the effective medical radiation dose. Use of CT angiography, which was rarely done prior to 2004 due to technical limitations, has risen dramatically; it now accounts for nearly 7 percent of all CT procedures. However, because CT angiography is a high-dose procedure based on multiple CT scans, it accounts for nearly 13 percent of the effective medical radiation dose.
- The distribution of CT scans across age groups is not equal. Data for abdominal and pelvic CT scans indicate that individuals over 55 years of age – who constitute approximately 20 percent of the population – receive more than 55 percent of CT scans.
- Overall, the benefits of radiological imaging outweigh the risks, but the high levels of radiation exposure at the population level are causing concern. Many patients receive multiple scans within a single CT exam, which can significantly increase their radiation exposure. The radiation dose resulting from certain types of CT scans has also increased.
- There are indicators that some patients may be receiving more CT scans than necessary. One study of pediatric patients undergoing bone marrow transplants was provided as an example. These patients should normally receive three scans: one prior to the transplant, one immediately following, and one 12 months after the transplant. Some patients in this study received as many as 13 scans. Although it is not known whether the additional scans were medically necessary, a closer examination of these practices is warranted.
- The ability to generate dose reports has become an increasingly common feature of CT scanners. These reports allow physicians to prospectively estimate the radiation exposure a patient will receive from a particular scan.
- Many clinical trials protocols involve multiple imaging scans over a specified period of time. These scans can result in very high cumulative radiation doses to trial participants. Thought should be given to whether repeat exams are necessary.
- There have been several positive developments in the effort to reduce radiation dose from CT. These include dose modulation techniques, which allow automatic changes to the radiation emitted based on patient thickness. These techniques can reduce radiation dose 30 to 40 percent; however, it is unknown what percentage of physicians/institutions are using these techniques.
- The American College of Radiology (ACR) has made efforts to reduce effective dose by including relative radiation levels (RRLs) as part of their Appropriateness Criteria for clinical decision-making. Imaging procedures are assigned to an RRL category (none, minimal, low, medium, high) based on their effective dose.

- ACR also has a CT accreditation program to promote optimum use of the technology and participates in the *Image Gently* campaign. *Image Gently* aims to reduce the radiation dose used in pediatric CT exams by encouraging physicians to downsize adult CT protocols and consider elimination of multiphase scans for children. A survey of members of the Society of Pediatric Radiologists indicates there has been a significant decrease in tube current and voltage settings since the campaign began.
- Additional research is necessary to help reduce exposure to medical radiation. Methods that provide better estimates of dose and risk for all imaging modalities are needed. Multicenter studies should also be initiated to assess current practices regarding protocol settings, repeat exams, and multiphase studies; protocols should be standardized based on data from these studies. Standardization of radiation dose data is also needed to allow comparison of exposure data across institutions. Finally, long-term follow-up studies of patients who have undergone multiple CT scans should be conducted.
- Appropriate regulations and policies are needed to stop or hinder the misuse of medical x-ray technology; x-ray modalities should be operated by qualified individuals at optimal settings with proper safety and quality assurance measures in place.
- The appropriateness of each medical imaging procedure should be justified. Care must be taken to ensure that benefits of imaging studies outweigh the risks, and repeat and multiphase studies should be minimized or eliminated. Equipment manufacturers, medical physicists, and physicians should coordinate their efforts to optimize modalities and protocols to minimize radiation exposure.
- All stakeholders must be educated regarding radiation doses associated with medical imaging. This topic should be emphasized as part of medical school curricula, and national conferences/dialogues should be held to highlight the risks associated with medical imaging.

DR. DAVID CARPENTER:

ELECTROMAGNETIC FIELDS AND CANCER: THE COST OF DOING NOTHING

Background

David Carpenter is currently Director of the Institute for Health and the Environment as well as Professor of Environmental Health Sciences within the School of Public Health at the University at Albany. After receiving his M.D. from Harvard Medical School, he conducted research at the National Institute of Mental Health and the Armed Forces Radiobiology Research Institute. In 1980, he moved to Albany as Director of the Wadsworth Center for Laboratories and Research of the New York State Department of Health. He initiated a partnership between the New York State Department of Health and the University at Albany that resulted in the creation of the School of Public Health in 1985. He was appointed founding Dean of the School of Public Health, a position he held until 1998 when he became the Director of the Institute of Health and the Environment. Dr. Carpenter's involvement on issues related to electromagnetic fields dates from his arrival in Albany, when he served as Executive Secretary to the New York State Power Lines Project, a \$5 million study designed to determine whether there were human health hazards associated with power line electromagnetic fields. After the program was completed in 1987 he became the spokesperson for New York State on issues related to electromagnetic fields. He has also served as an advisor to several other states on these issues, and has been a member of several national committees. Last September he testified on cell phone cancer risks before the U.S. House of Representatives Domestic Policy Oversight Subcommittee of the Committee on Oversight and Government Reform.

Key Points

- Three meta-analyses have shown significant elevation in rates of childhood leukemia in relation to residential exposure to electromagnetic fields (EMFs). Several national and international review bodies have commented on these studies. The National Research Council states, “The link between wire-code rating and childhood leukemia is statistically significant (unlikely to have arisen from chance) and is robust in the sense that eliminating any single study from the group does not alter the conclusion that the associations exist.” The World Health Organization says that, “...the epidemiological data...show an association between ELF magnetic field exposure and an increased risk of childhood leukemia.”
- Studies of adult leukemia and brain cancer in relation to EMF exposure primarily examine occupational exposure. Meta-analysis of these studies shows a small but significant elevation of risk for both types of cancer in spite of poor exposure assessment (i.e., according to job title and disregarding exposure from non-job sources). There has been only one study of both occupational and residential exposure, which showed significantly increased risk of adult leukemia.
- As of 2007, there were 3.3 billion cell phone subscriptions worldwide, which is equal to half the world’s population. The latency of brain cancer development from environmental exposures is thought to be 20-30 years. If cell phone use causes brain cancer, there will be a major public health problem that will worsen over time because of the rapidly increasing rates of cell phone use.
- Hardell and colleagues published a meta-analysis of mobile phone use and cancer in 2008 (*Int J Oncol.* 2008;32(5):1097-103). The analysis found that among individuals who had used cell phones for 10 or more years, risk of ipsilateral glioma was modestly but significantly elevated while risk of contralateral glioma was not significantly elevated. A study examining the risk of acoustic neuroma showed similar results.
- Kundi and colleagues conducted a meta-analysis of 33 studies of brain cancer and cell phone use (*Environ Health Perspect.* 2009;117(3):316-24). This study found increased risk of ipsilateral glioma and acoustic neuroma with long-term mobile phone use, but no significant increase in risk of meningioma.
- To date, there have been no published studies regarding mobile phone use and cancer among children. Results of one study of individuals who began to use mobile phones before 20 years of age were presented at a recent meeting; the data revealed a five-fold increase in risk of glioma among this population after more than one year of use.
- Studies in Italy and Korea have reported elevated levels of leukemia among children living near radio transmitter towers. These results indicate that while localized RF radiation causes local cancer (e.g., brain cancer from cell phone use), leukemia is the cancer of greatest risk for whole-body exposure.
- Currently, exposure assessment is very poor because it often relates risk to only one source of EMF exposure (e.g., cell phone use but not power lines). In reality, people are exposed to different sources of radiation virtually everywhere they go. Thus, it is likely that past studies have underestimated the risk of EMF exposure. This is particularly concerning when it comes to children, who are significantly increasing their use of mobile phones.
- One study revealed that 13 percent of homes in the U.S. are exposed to a magnetic field of 200 or more nano-Tesla; this compares to only 1-2 percent of homes in the United Kingdom. According to several of the above-cited studies, these U.S. levels of exposure are sufficient to increase cancer risk.

- Many national and international reports have recognized the relationship between EMF and cancer, but the issue has not been heavily pursued because the mechanism by which RF radiation causes cancer is unknown and there are no animal models in which to study the mechanism. This is in contrast to ionizing radiation, which is known to directly damage DNA and is given much more attention as a carcinogen. However, it must be recognized that not all carcinogens directly cause DNA damage. Lack of mutational capacity should not preclude RF radiation from being considered as an important carcinogen. There are other examples of nonmutagenic carcinogens, including arsenic and dioxins.
- Many cellular effects of EMFs have been demonstrated, including gene induction, indirect DNA damage through formation of reactive oxygen species, disruption of calcium regulation, and induction of heat shock proteins. Thus, although the exact mechanism of EMF-induced cancer is unknown, there are several potential mechanisms.
- The evidence for a direct relationship between power line frequency EMFs and cancer is very strong. The lack of a specific mechanism is not a good reason to ignore this evidence.
- The evidence for a relationship between RF exposure and cancer is emerging. There may be even greater long-term concerns regarding RF exposure because of the dramatic increase in the use of wireless devices, particularly by children.
- There are several steps that can be taken to reduce human exposure to 50/60 Hertz EMFs. Homes, schools, and businesses should not be situated near overhead power lines. Power lines should be buried as often as possible. Appliance and other electrical equipment manufacturers should be encouraged to build devices that do not generate large magnetic fields. Household wiring standards should be enforced in order to reduce ground currents and other sources of magnetic field generation. Children should be kept away from sources of high exposure.
- Several steps can be taken to reduce personal exposure to RF fields from cell phones. Landlines or text messaging should be used whenever possible. If a mobile phone must be used, a headset is preferable to holding the phone to the ear. Children should be prohibited from using mobile phones except in emergencies. Active phones should not be kept on belts or in pockets. Phones should not be kept in close proximity during sleep.
- Reduction of exposure to other sources of RF can be accomplished by keeping AM, FM, television, and mobile phone towers far from homes, schools, and businesses. Wireless networks should not be used in schools; wired connections should be used instead. There should be resistance to the general trend toward making everything wireless without consideration of negative consequences.
- Because of the evidence for elevated risk of childhood cancer in children exposed to power line fields of 2 to 5 milligauss, a standard exposure limit of 1 milligauss is recommended. For RF, a cautionary target level of 0.1 microwatt per square centimeter ($\mu\text{W}/\text{cm}^2$) is recommended. However, it is recognized that even these levels may not be completely safe. Imposition of these standards will have financial and lifestyle implications; however, given the growing evidence of adverse human health effects from RF exposure, this issue cannot be ignored.

DISCUSSION:

PANEL II

- There was general support for regulating medical radiation. One possibility would be to regulate physicians. Currently, any physician is allowed to perform an x-ray examination, but many practicing physicians are unaware of the risks associated with these procedures.

Another option would be to regulate the radiation released from specific scanners; a reference level could be established and scanners would be prohibited from exceeding that level unless justification could be provided. The American College of Radiology is using a similar approach in their accreditation programs; however, physicians and institutions do not need to be accredited to perform x-ray exams. “Self-regulation” of medical radiation exposure was also advocated. If information about the risks of medical radiation is published and disseminated by the media, the general public will demand improvement and manufacturers will likely respond to these market forces.

- There are also a number of potential challenges and drawbacks to regulation of medical radiation. There is currently no government body with authority to regulate this area; one speaker noted his belief that the Food and Drug Administration (FDA) would not be interested in assuming this responsibility. Also, regulations can be slow to adapt to new technologies; for example, digital mammography was shown to be an effective screening technique, but most digital scanners surpass established dose limits, which were based on traditional mammography.
- Participants discussed the best ways to inform patients about risks associated with medical radiation exposure. One option would be to establish informed consent for procedures involving radiation exposure; however, it may be difficult to quantify the relative risks and benefits of a procedure based on available data. Rather than imposing the burden of informed consent, it may be sufficient to simply provide patients with information to help them make educated decisions. It was recognized that providing the public with information can have detrimental effects—media coverage of radiation exposure associated with certain procedures could instill fear in patients and prevent them from receiving medically warranted exams.
- There is some regulation in the field of nuclear medicine. NRC and its Agreement States license and regulate the possession and use of radioactive materials for nuclear medicine. Attainment of NRC authorized user status for nuclear medicine equipment requires certification by a medical specialty board whose certification process has been recognized by NRC or an Agreement State. American Board of Radiology certification exams include questions developed with help from NRC.
- Much of the knowledge about risks of radiation exposure is based on the effects of radiation on the Hiroshima population, which experienced acute exposure to high doses of radiation. Although some patients are exposed to medical radiation over a longer period of time than the Hiroshima population, the risk they experience is approximately equivalent (i.e., dose fractionation over time does not significantly reduce risk).
- Radiation increases the risk of malignancy in all exposed tissues; however, the actual risk of an exam will depend on which organs are exposed. For example, the brain and thyroid will be affected during a head CT scan. Also, different tissues have different sensitivities to radiation. Bone marrow, thyroid, and breast are more sensitive than the prostate or cervix. Physicists use sensitivity factors in their calculations to reflect the magnitude of the radiation effect on particular tissues. These sensitivity factors are estimates based on previous research and experiences and are continually being refined.
- Various factors influence what type of scan is performed. CT scans with and without contrast will permit visualization of different features. A scan without contrast is better for identification of kidney stones or fresh blood; however, obtaining scans both with and without contrast is often useful for differentiating liver cancer from other liver conditions. Cost, speed, and availability often determine what type of exam is conducted. A CT scan can be completed much more quickly than an MRI scan. Some cities and institutions have access to one type of machine, but not others. Also, there are safety concerns; great care must be

taken if MRI scans are performed on patients who have defibrillators, other devices with magnetic components, or oxygen tanks.

- Some people are more susceptible than others to radiation-induced damage. For example, women with BRCA1 mutations have a higher risk of breast cancer, which suggests they should be screened more frequently than other women. However, they may also be more sensitive to mammography-associated radiation than other women. More research is needed to determine how these types of factors influence the balance of risks and benefits of mammography and other procedures involving medical radiation exposure.
- Like all medical procedures, CT is associated with some risks. On an individual level, the risks are relatively small, but on the population level, these risks are significant and must be addressed. A significant number of CT scans conducted are unnecessary; this fraction may be as high as one-quarter to one-third. Unnecessary CT scans should be prevented to help lessen the population risk of this procedure.
- The general public may be surprised to learn that overall exposure to radiation has doubled since 1980 because of increased use of medical radiation. Radiation is a relatively poor carcinogen, but, because of the population risk, the issue of medical radiation should be thoughtfully considered and addressed.
- Ongoing studies are examining whether children who have CT scans are more likely to develop leukemia.
- Education regarding radiation doses and risks is important. Policies or regulations should be developed to establish an acceptable relative radiation dose for CT. Relative radiation level information should also be more uniformly used for clinical decision-making.
- Although there appears to be a relationship between cancer and extremely low-frequency radiation exposure, more work needs to be done to establish a mechanism for this phenomenon. Also, incidence of brain cancer, particularly glioma, and other types of cancer has increased concomitantly with use of cell phones and other modes of wireless communication. Although not all of the data are conclusive, this area should receive attention from the U.S. Government.

PUBLIC COMMENT

- The Electrical Power Research Institute (EPRI) is a nonprofit research and development organization primarily funded by the electric utility industry. EPRI has conducted EMF research since it was founded in 1973 and continues to have a very active research program in this field. It has published numerous studies regarding the health implications of EMF exposure, including cancer risk. EPRI has reported both positive and negative associations between EMF and risk of health problems.
- EMF research would benefit greatly from the availability of a transgenic mouse that develops B-cell leukemia through a mechanism similar to that observed in children. There have been efforts to develop such a mouse for close to a decade, without success. EPRI is currently funding a laboratory at the University of California, Los Angeles to attempt creation of such a mouse model.
- An update to a past meta-analysis on EMF and brain cancer was published by Leeka Kheifets in 2008. The study reveals lower pooled risk estimates than those calculated by previous meta-analyses.
- There are several gaps in the data regarding EMF exposure and cancer risk for humans. There is a dearth of EMF dose-effect data in humans, particularly for low-dose EMF exposure. Furthermore, the biological mechanisms by which EMF may damage tissue are unknown.

- There have been relatively few studies regarding residential exposure to radiofrequency radiation. These studies are made somewhat difficult by the fact that people are in constant motion, which results in an ever-changing proximity to sources of these types of radiation.
- Researchers at Colorado State University conducted a study of the radiofrequency (RF) radiation exposure of approximately 300 residents who live on Colorado's Lookout Mountain, which also houses broadcast antennae towers. Participants wore hats that measured their level of radiation exposure over a 48-hour period. Blood and urine were also collected. These studies confirmed high levels of radiation exposure among Lookout Mountain residents and documented biological effects of this exposure, including elevated lymphocyte levels. Estrogen levels were also elevated in postmenopausal women with low levels of melatonin. There was an effort to rezone the area to prevent erection of a broadcast super tower. Physicians and research scientists testified on the risks that might be imposed on residents. However, the effort failed and a super tower that emits higher-power radiation is now in place.
- The general public has not been adequately informed about risk factors for cancer. More emphasis must be placed on cancer prevention strategies (those efforts that aim to reduce cancer incidence by lessening the stressors that cause the disease). Mammography and other types of cancer screening are not prevention strategies; rather, these procedures are focused on early detection. The U.S. should set tangible goals for reduction of exposure to materials implicated in cancer causation.
- NCI has fact sheets with updated information on cell phone use, extremely low-frequency radiation, CT scans, and other topics related to radiation exposure and cancer risk.
- The Federal government has funded multiple studies on extremely low-frequency radiation. For example, one study investigated whether there is greater and/or more significant exposure to extremely low-frequency radiation at night. Another study involved visiting current and former homes of children with and without leukemia to better assess lifetime exposure to radiation, including exposure from electrical appliances. Cancer associations were found for both microwave use and television viewing. Phantoms (devices or objects used to simulate conditions of interest for research) have also been used to measure typical exposures of children watching television.
- Meta-analyses are very important for synthesizing available data regarding risk; however, not all meta-analyses are equally informative. These analyses are much more powerful if the data were collected and combined according to a well-defined protocol.
- Meta-analysis of studies in the U.S. has shown that extremely low-frequency radiation increases risk of childhood leukemia only when exposure levels are above a certain threshold. There is interest in doing a study on high-level exposure, but it has been difficult to identify a study population. One option is Asia, where electrical power lines can be very close to homes.
- Thermography and ultrasound are breast cancer screening alternatives to mammography that could help avoid radiation exposure. Some studies have shown that these approaches are effective, although, overall, they are not as sensitive as mammography. However, these approaches may be a good alternative for women who may be highly susceptible to radiation-induced damage.

PANEL III

DR. NEAL PALAFOX:

U.S. THERMONUCLEAR WEAPONS TESTING, PACIFIC, IN THE MARSHALL ISLANDS

Background

Dr. Neal A. Palafox is Professor and Chair of the Department of Family Medicine and Community Health at the John A. Burns School of Medicine, University of Hawaii. He completed his residency in Family Medicine at the UCLA Health Center for Clinical Sciences and obtained a master's in public health from Johns Hopkins University. He went to the Marshall Islands in 1983 as a National Health Service Corps physician, where he became co-medical director of a U.S.-funded program to care for the radiation-affected people of the Marshall Islands in 1985. He spent the last five years of his nine-year tenure in the Marshall Islands as Director for Preventive Health Services and Public Health. His areas of research and publication include human health resource development, cancer systems development, health care disparities, cultural competency, vitamin A deficiency, Pacific health care, and ciguatera.

Key Points

- Operation Crossroads, the nuclear weapons testing period from 1946-1958, occurred post-World War II after the United States invaded and occupied the Marshall Islands, adding them to the U.S. Trust Territory of the Pacific Islands. The Marshall Islands span 750,000 square miles of ocean and are fairly isolated, which was the basis for using them for nuclear testing. The two main atolls used for testing were Bikini and Rongelap. It was thought that their distance from the surrounding islands and the United States was significant enough to protect residents of these areas from the detrimental effects of the nuclear material.
- There were 67 nuclear tests during Operation Crossroads, which yielded levels of radioactive material equivalent to 7,200 Hiroshima bombs. This equates to exploding 1.6 Hiroshima bombs per day for 12 years in the Marshall Islands – producing a significant amount of radiation over time. As a comparison, only 9 of the 67 bombs detonated in the Marshall Islands were smaller than the 15-kiloton bomb that was dropped on Hiroshima. In fact, 18 of the 67 bombs were greater than 1,000 kilotons (1 megaton).
- Ivy Mike, a 10,400-kiloton bomb, was considered the first successful test of a hydrogen bomb and was used as an experiment to test the concept of multi-megaton bombs. The fireball from Ivy Mike was 3.25 miles in diameter and the nuclear cloud was 10 miles high and 100 miles wide 10 minutes after detonation. The crater that the bomb created was 175 feet deep at the center – the height of a 17-story building – and could hold approximately 14 Pentagon buildings. The bomb would have annihilated anything within a 3-mile radius.
- Castle Bravo, the thermonuclear hydrogen bomb that was considered the first practical fusion bomb in the U.S. arsenal, was the last bomb detonated on the Marshall Islands. It was equal to 1,000 Hiroshima bombs and vaporized the entire test island and parts of two surrounding islands. The fallout covered 7,000 square miles. The drift cloud from this detonation, which shifted from its projected path due to wind patterns, affected 636 inhabitants of four atolls.
- Following the Castle Bravo test in 1954, Russia set off a 55-megaton bomb, which was twice the size of Bravo. The magnitude of these bomb tests prompted the U.S. and Russia to end the Cold War. Both countries understood the mass destruction that could occur should these bombs be used as weapons of war.

- The outcomes of the Marshall Island bombings include direct fallout (the radioactive substances released into the air) on residents of multiple atolls, long-term radiation and food chain contamination, vaporization of some of the islands, and destruction of culture and communities. This translates into many biomedical, biopsychosocial, political, economic, moral, and spiritual health ramifications that have yet to be addressed adequately by the United States government.
- Inhabitants of the two atolls used for bomb detonation had lived there for hundreds of years prior to the U.S. moving them off their ancestral lands to other islands or to landing crafts. They were told they would be returned to their homes when the testing was finished. Some residents were permitted to return for a brief period of time after the conclusion of testing in 1958, but high levels of contamination forced them to leave their homes again and the islands remain uninhabitable in 2009. This has led to a breakdown of social and cultural balance, ultimately destroying entire community structures.
- The Pacific U.S. Nuclear Weapons Testing Program subjected the Marshall Islands residents to both acute and chronic radiation exposure. It is estimated that residents of the Marshall Islands received the equivalent of 2 Sv of direct radiation from the fallout, which is equal to 2,000 times the dose of a CT scan. Acute exposure resulted in beta burns, bone marrow suppression, hypothyroidism, and, in some cases, death. Chronic exposure to radiation contamination caused increased risk of cancer.
- Evidence from a National Cancer Institute report presented to the Senate Committee on Energy and Natural Resources in 2004 shows that the fallout covered the entire Marshall Islands – 33 atolls – which is in direct contrast to the Department of Energy’s position that only 4 atolls were affected. The NCI report estimates there are 530 excess cancers expected from the nuclear testing, with 56 percent of these yet to manifest due to latency periods.
- There are inconsistencies in the information being presented to policy makers by Federal agencies regarding the Nuclear Testing Program: the Department of Energy has taken one position and NCI has taken another. This has led to a disconnect between science and policy, in turn causing disparities in health care access and treatment for those affected by the Nuclear Testing Program, as compared to the general U.S. population. Policy being applied to victims of the Hanford and Nevada nuclear test sites should be applied to Marshall Island residents and workers as well to help reduce health disparities and address social injustices.
- It is imperative that a sense of urgency be established and that policies be applied equitably to all individuals affected by nuclear testing. The residents of the Marshall Islands deserve the same recognition and healthcare as those impacted by the Hanford and Nevada test sites. A lot of progress was made through nuclear testing; however, the health implications still exist 61 years after testing began, underscoring the importance of making those affected a priority and conducting additional research on the future health implications of the nuclear testing program.

MS. TRISHA THOMPSON PRITIKIN:

CHILDHOOD EXPOSURES TO U.S. AND GLOBAL FALLOUT

Background

Ms. Trisha Pritikin was born and raised in Richland, Washington, during years of chronic offsite emissions of radioiodine and other radioactive substances from the Hanford nuclear weapons production facility. Her father was a nuclear engineer at Hanford. Her childhood years were also a time of global nuclear testing. Ms. Pritikin has been involved in fallout-exposure health issues for over two decades, since first understanding that her family’s health problems were likely the

result of Hanford's radiation releases. She was a member of the Hanford Health Effects Subcommittee until the Subcommittee was disbanded in 2004. She continues to serve as the co-chair of what was originally called the Hanford Health Information Archives (now a 501(c)(3) organization called the Radiochemical Health Effects Archives). In 1999, Ms. Pritikin served as a panelist at the Third Annual University of Washington Conference on the Ecological, Community, and Occupational Issues at Hanford, addressing "Hanford Releases, Hanford Thyroid Disease Study, Individual Dose Assessment, and Next Steps." She also served as co-chair of the Hanford Health Information Network advisory board for many years.

Key Points

- The Hanford Project, a nuclear production site established in 1943 Washington state, manufactured most of the 60,000 weapons in the U.S. nuclear arsenal. It was fully decommissioned by 1972, leaving behind 53 million gallons of high-level radioactive waste. It is now considered the most contaminated nuclear site in the United States.
- The health of the residents and workers at the Hanford Project was threatened by the release of radioactive materials into the air and the Columbia River. Residents' exposure came from numerous sources including global fallout, Nevada Test Site airborne radionuclides, and fallout from the Marshall Islands testing, making exposure assessment complex.
- The children who grew up near DOE facilities have become a forgotten population in terms of assessing their increased health risks and informing them of their exposures. As adults, they are unaware of their levels of exposure to radionuclides and their risk for developing certain health issues. Nuclear workers know their levels of radiation exposure and have been made aware of the diseases for which they should be screened. However, the residents of these nuclear testing areas have only been given information about their exposures to one radionuclide, iodine-131, a radioactive form of iodine.
- The National Cancer Institute created an I-131 Dose/Risk Calculator to help individuals determine their estimated thyroid dose from exposure to I-131 from nuclear testing site fallout. This calculator takes into account individual risk factors in regards to I-131. It is crucial that other radionuclides be assessed in this same manner. It would also be beneficial for those affected to have the ability to ascertain their cumulative dose of the same radionuclide from separate sources.
- The Advisory Committee on Energy-Related Epidemiologic Research (ACERER) was created in 1992 by the CDC to advise the Department of Health and Human Services on dose reconstruction and epidemiologic research at DOE sites involved in nuclear weapons production and testing. In response to an NCI study that concluded Americans were exposed nationwide to fallout, ACERER recommended that those with the highest doses of radiation exposure be informed of their exposure and educated about potential risks. ACERER also suggested the government consider providing these individuals access to free screening for thyroid disease and cancer. The charter for this committee expired in 2002.
- The CDC evaluated the feasibility and health implications of conducting a study of Americans affected by radioactive fallout from 1951-1962. The CDC report concluded that, "...a more detailed study of the health of American people of exposure to radioactive fallout from the testing of nuclear weapons in the United States and abroad is technically possible." However, the report also stated that the study would be costly and urged careful consideration of health priorities before funding dose reconstruction and risk assessment at DOE sites.
- In 2005 the CDC/National Center for Environmental Health terminated an epidemiological study of Utah children exposed to fallout from nuclear testing sites due to uncertainty of techniques used in the study and decreased funding. However, early results of this study confirmed an association between nuclear testing site fallout exposure and thyroiditis and

thyroid neoplasms. It was determined that further follow-up of study participants was necessary.

- It is imperative that the nationwide dose reconstruction database and dose assessment formulas be expanded beyond I-131. Furthermore, funding should be restored to the Utah Thyroid Cohort Study, and the ACERER should be rechartered to provide a forum for public participation. These actions will ensure that those affected by nuclear test site exposures are not forgotten and justice is served.

DR. MICHAEL LERNER:

RESEARCH AND POLICY OPTIONS FOR THE PRESIDENT'S CANCER PANEL REPORT

Background

Michael Lerner, Ph.D., is President of Commonweal, a health and environmental research institute in Bolinas, California, and of Smith Farm Center for Healing and the Arts in Washington, DC. He is also President of the Jenifer Altman Foundation and the Barbara Smith Fund, and Chair Emeritus of the Health and Environmental Funders Network. Dr. Lerner is co-founder of the Commonweal Cancer Help Program, featured by Bill Moyers in his award-winning PBS series, "Healing and the Mind." As part of the Cancer Help Program, Dr. Lerner has led over 160 week-long retreats since 1985. He is the author of "Choices in Healing" from MIT Press. He served for over a decade on the American Cancer Society's CEO Advisory Board. He is a co-founder and Vice Chair of the Collaborative on Health and the Environment, an international partnership of over 3,000 individuals and organizations concerned with environmental health promotion and disease prevention. A Harvard graduate with a doctorate in political science from Yale, Dr. Lerner received a MacArthur Prize Fellowship for contributions to public health in 1983.

Key Points

- Cancer prevention needs to be made a national priority: the current healthcare system needs to be redirected to focus on health promotion and disease prevention. Evidence has shown that actions taken to reduce cancer incidence also reduce the incidence of many other health issues, such as infertility and asthma.
- Environmental factors play a role in the vast majority of cancers; thus, emphasis should be placed on research of environmental cancer causation and environmental cancer prevention. The Doll and Peto study has been cited for 30 years as a reference for the number of cancers related to industrial and occupational exposures. It estimated that only 5 percent of cancers were related to environmental exposures. Although this estimate was appropriate when the study was published, advances in scientific research methods and the complexity of this issue make this study an unreliable source in 2009.
- Low socioeconomic status correlates with higher levels of environmental exposures (e.g., industrial, manufacturing, and transportation contaminants) and a number of diseases; thus, individuals of low socioeconomic status are an important consideration when examining environmental cancer causation. They tend to be under the most environmental stress – socioeconomic, nutritional, and occupational – in turn having higher total mortality, morbidity, and cancer incidence rates than the general population. Reducing the disadvantages faced by vulnerable populations will enhance public health and reduce overall mortality.

- Implementation of policy to reduce public exposure to carcinogenic contaminants will reduce cancer incidence and should be considered by the Federal and state governments. The European Union, Canada, and several U.S. states have taken a precautionary approach when creating policy to reduce environmental contaminants, making cancer risk reduction a priority.
- Green chemistry offers promise for cancer risk reduction, and investment in this area by the public and private sectors should be encouraged. Compounds synthesized using green chemistry may have lower toxicity than other chemicals on the market, which would translate to a reduction in public exposure to carcinogenic contaminants.

DISCUSSION:

PANEL III

- The NCI research portfolio needs to be examined and rebalanced to address the current state of knowledge regarding cancer causation, prevention, and treatment. The dissemination of this research also needs to be evaluated in terms of determining who is responsible for presenting it to the population.
- The residents of the Marshall Islands have been an invisible population as no one has taken responsibility for their unintended exposure to nuclear testing. NCI is currently researching this population; however, this does not excuse the lapse in time that has occurred between their exposure and the present. The longer this population remains invisible, the larger the public health liability will become. It is imperative that their health needs are made an urgent priority.
- The United States needs to take a stand in issuing warnings about the use of cell phones, especially by children. Other countries have taken a precautionary approach with this issue and are basing their warnings on the same science available in the U.S.

PUBLIC COMMENT

- Finding an alternative to mammography for breast cancer screening needs to be made a priority. Mammography is used widely for screening women for breast cancer; however, studies have shown that the radiation dose received from this procedure can be carcinogenic. Many of the women screened will never have breast cancer, making mammography an unnecessary exposure to an environmental carcinogen.
- Physicians should use caution when referring patients for procedures that involve radiation, such as mammograms. These procedures are practical for diagnosis, localization of tumors, and screening those believed to be at higher risk, but they may not be the best option for general screening.
- Policy needs to be created requiring all professionals performing radiologic procedures to be licensed; licensing is currently not required in seven states, making the practice of these procedures in those states a public health liability.
- The National Cancer Institute has been expanding the study conducted in 2004 on the doses of radiation received by residents of the Marshall Islands. This study aims to calculate the risk assessments and risk projections for future cancer incidence and should be published in 2009.
- Residents of base quarters in Camp Lejeune, North Carolina, were unknowingly exposed to contaminated water from 1957 to 1985. Many individuals who lived on the base during that time are unaware of their exposure to the contamination. Those who have been informed

were contacted by the University of Chicago to participate in a study examining birth defects of children linked to Camp Lejeune. Advocates are seeking further research on the implications of this water contamination, but have been unsuccessful in gaining the attention of Congress and the DOE.

CLOSING REMARKS—DR. LEFFALL

- Dr. Leffall thanked the attendees and panelists for making valuable contributions and assured them that the Panel would carefully consider the information collected at the meeting.

CERTIFICATION OF MEETING SUMMARY

I certify that this summary of the President’s Cancer Panel meeting, *Environmental Factors in Cancer*, held January 27, 2009, is accurate and complete.

Certified by: _____ Date: April 14, 2009

LaSalle D. Leffall, Jr., M.D.
Chair
President’s Cancer Panel