Radiation Protection in Medicine

sponsored by the National Council on Radiation Protection and Measurements

Tuesday, January 28, 2020

7:15 am

Kathryn D. Held

National Council on Radiation Protection & Measurements and Massachusetts General Hospital/Harvard Medical School

President of NCRP; Associate Radiation Biologist in the Department of Radiation Oncology, Massachusetts General Hospital and Associate Professor of Radiation Oncology (Radiation Biology) at Harvard Medical School. Dr. Held was a member of Scientific Committee (SC) 1-22 on Radiation Protection for Astronauts in Short-Term Missions and Phase I of SC 1-24 on Radiation Exposures in Space and the Potential of Central Nervous System Effects and an advisor to several NCRP committees.

Radiation Biology for Radiation Protection in Medicine [Continuing Education Lecture]

A good understanding of basic radiation biology concepts and new information and research approaches is critical for understanding and applying radiation protection in medicine. In recent years there has been a plethora of new thoughts and data derived using “modern” molecular biology techniques that impact the application of biology knowledge to radiation protection approaches for patients and medical workers, particularly in the low dose and low dose rate arena. In addition to knowing “classic” concepts such as acute and delayed effects on irradiated normal tissues, sparing by low dose rates and radiation carcinogenesis, a medical and health physics practitioner should now be familiar with concepts such as bystander effects, genomic instability, DNA damage repair fundamentals, and genomics and proteomics. This lecture will provide an overview of important radiation biology fundamentals relevant to protecting patients and medical workers exposed to radiation, as well as an introduction to newer findings that could impact future approaches to protection. The lecture will complement the talks to be given in the NCRP Symposium on Radiation Protection in Medicine.

Plenary, 8:25-9:30 am

Donald L. Miller

Center for Devices & Radiological Health, U.S. Food & Drug Administration

Dr. Miller, an interventional radiologist, is Chief Medical Officer for Radiological Health at the U.S. Food and Drug Administration’s Center for Devices and Radiological Health. He is a member of NCRP’s Board of Directors, chairs Program Area Committee 4, and serves on several NCRP scientific committees. He has been a member and Vice-Chair of International Commission on Radiological Protection Committee 3. Dr. Miller was previously Professor of Radiology at the Uniformed Services University in Bethesda, Maryland.

Overview of NCRP Activities (Emphasis on Radiation Protection in Medicine)

The National Council on Radiation Protection in Medicine (NCRP) was chartered by Congress in 1964 but had its beginnings in 1929, as the U.S. Advisory Committee on X-Ray and Radium Protection. NCRP’s mission is to support radiation protection by providing independent scientific analysis, information and recommendations that represent the consensus of leading scientists. The Council consists of up to 100 individuals, selected for their scientific expertise, who are elected to six-year terms. They serve on scientific committees and review all NCRP documents prior to publication. NCRP produces reports, commentaries, and statements. These documents originate in program area committees (PACs) or Council committees (CCs). PACs provide expertise in specific areas of radiation protection: epidemiology and biology, operational radiation safety, security and safety, medicine, environment and waste, dosimetry and measurements, and risk communication and outreach. CCs include members from each PAC and deal with general or overarching issues in radiation protection. CCs produced NCRP Report No.180 (*Radiation Protection Guidance for the United States*) and are developing a commentary on meeting the needs of the nation for radiation protection. This presentation describes recent NCRP publications and introduces current NCRP work, with special emphasis on the work of PAC 4 (Radiation Protection in Medicine). As shown by NCRP Report No. 160 (*Ionizing Radiation Exposure of the Population of the United States*), radiation use in medicine is now responsible for approximately one-half of the total radiation exposure of the U.S. population.

Session 1: Radiation Protection in Medicine: Safety-Related Issues
Kathryn D. Held & Jerrold T. Bushberg, *Co-Chairs*

10:00 am

Keith J. Strauss
University of Cincinnati School of Medicine
Research: development of configurations of imaging equipment that achieves diagnostic image quality at well managed radiation doses during pediatric imaging of children. Professional organizations: American Association of Physicists in Medicine, American College of Radiology, Society for Pediatric Radiology, International Electro-Technical Commission, International Atomic Energy Agency, National Council on Radiation Protection and Measurements, Radiological Society of North America, Image Gently® Alliance.

Gonadal Shielding During Abdominal & Pelvic Radiography (NCRP Scientific Committee 4-11)
Gonadal shielding during abdominal and pelvic radiography for adults and children has been considered good practice for more than 60 y. However, the efficacy of gonadal shielding has recently been questioned. Recent data on the limited effectiveness of gonadal shielding is presented for both males and females, but especially females. First, since automatic exposure control (AEC) capability of current equipment has replaced most manual techniques, the dose to the gonads and surrounding abdominal organs can increase when the shields cover the AEC sensors. In addition, the International Commission on Radiological Protection has revised tissue weighting factors with the colon, stomach, and bone marrow unchanged at 0.12 while reducing this factor for the gonads from 0.2 to 0.08. Thus, gonadal shielding and the impact of AEC are focused on protecting a less sensitive organ while actually increasing the radiation dose to more sensitive surrounding organs. Discontinuing a “good practice” is difficult when patients and/or their parents, regulatory agencies, and medical professionals (radiologic technologists, physicians, medical and health physicists) expect consistency and tradition. This presentation includes recommendations and guidance on the actual merits of gonadal shielding for all relevant professionals. These individuals are custodians for patients and or their parents for understanding that their imaging experience is evolving to deliver the best possible care.

10:25 am

Stephen Balter
Columbia University
Professor of Clinical Radiology (physics) and Medicine at Columbia University. He is an international authority on most aspects of medical fluoroscopy. Dr. Balter is a member of the NCRP Council. He served as the char of NCRP Report No.168 and NCRP Statement No. 11. Dr. Balter is currently responsible for fluoroscopy guided imaging (FGI) quality and radiation management in a clinical service that performs over 10,000 FGI procedures per year.

Patient Radiation Management in Interventional Fluoroscopy
Image-guided interventional medical procedures often require fluoroscopy (FGI) for their completion. This can result in the delivery of substantial amounts of radiation to the patient. FGI patients are accepted for a procedure when the benefits of that procedure are expected to outweigh the associated risks (radiation and others). Radiation use poses a stochastic risk and may also induce tissue reactions. Optimization involves complex interactions between patient characteristics, the capabilities of available fluoroscopes, and the operator. FGI differs from most imaging procedures (*e.g.*, computed tomography) in that the operator continually interacts with the fluoroscope during the procedure, and that changes in the patient’s condition will influence the operator’s options. Unfortunately, about 10 major tissue reactions occur each year around the world. Most of these are not justified and are attributable to operator factors. NCRP Report No. 168 (*Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures* - 2010) and Statement No. 11 (*Outline of Administrative Policies for Quality Assurance and Peer Review of Tissue Reactions Associated with Fluoroscopically-Guided Interventions* - 2014) provide necessary detailed guidance. This presentation will review key guidance elements and present data demonstrating considerable radiation use reduction in the past decade.

10:50 am

Alan G. Lurie
University of Connecticut School of Dental Medicine
Professor and Chair of Oral and Maxillofacial Radiology (OMFR) at the University of Connecticut Dental School. He is Past President of the American Academy of Oral and Maxillofacial Radiology, Past Director and President of the American Board of Oral and Maxillofacial Radiology, and founding and Past Chair of the Image Gently® in Dentistry Group. With 100+ publications in refereed literature, he Co-Chaired NCRP SC-45, preparing Report No. 177, *Radiation Protection in Dentistry and Oral & Maxillofacial Imaging*. He is dental and OMFR representative on NCRP.

Radiation Protection In Dentistry and Oral & Maxillofacial Radiology (NCRP Report No. 177)
Diagnostic imaging is essential in dentistry. Doses range from low to very low, benefits to patients can be immense, and safe techniques are well known but widely ignored. Doses range from very low with properly executed intraoral, cephalometric and panoramic imaging to higher than multidetector computed tomography (MDCT) with conebeam computed tomography (CBCT). Benefits are substantial: imaged dental disease, often obscured from direct vision by size and anatomy, can pose a mortal threat to the patient. Additionally, imaging is often central in planning complex dental procedures. NCRP Report No. 177 addresses the methods by which safety and diagnostic efficacy in dentistry are maximized. Safe imaging in dental environments is straight-forward; the means for minimizing dose and maximizing diagnostic efficacy have been widely and inexpensively available for decades. Digital receptors and rectangular collimators, coupled with stable receptor holding and directional devices, reduce patient dose by some

80 % over traditional techniques but are infrequently used. Digital panoramic equipment reduces doses markedly. For CBCT imaging, selection criteria are critical in defining appropriate fields-of-view and equipment presets. It is treacherous to discuss risk in oral and maxillofacial radiology. There are between one and two billion dental x-ray examinations annually, the majority being intraoral examinations, with steady increases in panoramic and CBCT. Radiation carcinogenesis from conventional imaging is unlikely, although large field-of-view, high-resolution preset CBCT can be comparable in carcinogenesis risk to craniofacial MDCT. Uncertainties in risk estimation from low doses, coupled with the huge numbers of dental images taken annually and the rapid growth of CBCT imaging dictate that safe oral and maxillofacial imaging is in the interests of patients, staff, and members of the public. “As low as reasonably achievable” practices and linear non-threshold risk modeling continue to be prudent and appropriate.

11:15 am

Steven G. Sutlief

Banner MD Anderson Cancer Center

Medical physicist at the Banner MD Anderson Cancer Center. His interests include quality assurance. He currently chairs an American Association of Physicists in Medicine (AAPM) Working Group and Task Group, is a Council member of the NCRP, and serves as an associate editor for *Medical Physics*. He graduated from the University of Washington in high energy physics, where he received further training in medical physics. Dr. Sutlief is a fellow of the AAPM.

Program Components for Error Prevention in Radiation Therapy (NCRP Scientific Committee 4-10)

Considerable efforts have been made in recent years to refine principles of quality and safety in radiation therapy. The intent of this NCRP statement project is to provide a short guidance document for external assessment of a radiation therapy department in terms of quality and safety. The statement will be of value to external reviewers as a guide for quality and safety assessment, to radiotherapy departments as a source of practice improvement initiatives, and to facilities for the assessment of accreditation readiness. Three themes of the statement are the assessment of documentation, metrics, and processes as indicators of quality and safety. Documentation is an essential tool for demonstrating quality and encompasses physician and physicist peer review, commissioning of new modalities and equipment, machine and patient quality-assurance records, and policies and procedures. Metrics include staffing levels, participation in remote dosimetry programs such as by the Imaging and Radiation Oncology Core Houston Quality Assurance Center, incident reporting participation, and the presence of in-service continuing education. Process techniques that aid safety include time outs, sterile cockpit, and shared authority to halt a procedure. This document differs from quality and safety initiatives and reports from professional organizations in that its scope specifically targets external review.

11:40 am

Lisa R. Bruedigan

Texas Department of State Health Services

Radiation Unit Manager, Surveillance Section in the Radiation Control Program. She has 38 y of experience with radiation protection with 22 y at the Texas Department of State Health Services. Ms. Bruedigan is a Texas Conference of Radiation Control Program Directors (CRCPD) member and served on CRCPD’s Board of Directors for 3 y. She currently serves on several CRCPD committees and is their liaison to the American College of Radiology.

The Role of the Conference of Radiation Control Program Directors & State Radiation Control Programs in Radiation Protection in Medicine

The state radiation control programs regulate the use of radiation producing machines in medicine. The Conference of Radiation Control Program Directors (CRCPD) is a partnership of the state radiation control programs whose mission is to promote consistency in addressing and resolving radiation protection issues, encourage high standards of quality in radiation protection programs, and provide leadership in radiation safety and education. State programs are challenged with the exceedingly difficult task of maintaining regulations that adequately protect patients, workers and caregivers as innovations in technology result in new ways to use ionizing radiation for improved diagnostic, interventional and therapeutic purposes. The goals of CRCPD include providing up-to-date guidance and suggested state regulations on the safe use of ionizing radiation in medicine in an effort to assist the states with the development of standards and policy based on sound science and professional consensus.

12:05 pm

Julie K. Timins

Has practiced Radiology and Nuclear Medicine in New Jersey in various settings: Nuclear Medicine Chair at a Veterans Administration Hospital, Staff Radiologist at Robert W. Johnson University Hospital and an inner-city hospital, and mammography in an outpatient facility. She chairs the New Jersey Commission on Radiation Protection. Dr. Timins served on the NCRP Board of Directors. She has been active in American College of Radiology, Radiological Society of New Jersey, and American Association for Women Radiologists.

Evaluating and Communicating Radiation Risks for Studies Involving Human Subjects: Guidance for Researchers & Institutional Review Boards (NCRP Scientific Committee 4-7)

Because of the need for a comprehensive approach guiding human studies research involving radiation, NCRP is developing a guidance document: “Evaluating and Communicating Radiation Risks for Studies Involving Human Subjects: Guidance for Researchers and Institutional Review Boards.” This report is targeted to those developing research protocols and to members of Institutional Review

Boards. There are widely varying levels of knowledge about ionizing radiation and radiological procedures among members of the public, medical professionals, and even among radiologists. The report addresses these knowledge gaps, starting with a history of international and national guidance on human studies research in general, and specifically research involving ionizing radiation. The fundamental principles of radiation biology are discussed, the basic quantities and units used in describing radiation dose are defined, and the basic principles of radiation protection are presented. Regulatory requirements for research are summarized, with links to the relevant regulations in the reference section. Imaging modalities and image-guided interventional procedures are described, including which *do* and which *do not* employ ionizing radiation. There is discussion of radiation therapy and radionuclide therapy. The need to distinguish between the radiation related to the research protocol and radiation encountered in standard patient care is examined. Estimation of radiation dose and radiation risk, and optimization of radiation dose are addressed. There is a discourse on ethics in human studies research, followed by the elements necessary for informed consent.

Session 2: Radiation Protection in Medicine: Doses, Dosimetry and Low Dose Considerations

Kathryn D. Held & Donald L. Miller, *Co-Chairs*

2:00 pm

David C. Spelic

U.S. Food & Drug Administration

Physicist with FDA. He received his PhD in physics in 1994, and shortly thereafter joined the Agency, where he supported activities directed at mammography quality. Dr. Spelic presently conducts numerous medical x-ray imaging activities including standards development, collaborations with professional organizations, and the review of premarket submissions from x-ray device manufacturers.

Radiological Health at FDA: A Review of Programs & Findings, Past & Present

FDA has a long history of radiological health activities directed at medical x-ray imaging. Beginning with two benchmark studies of population exposures conducted in the United States during 1964 and 1970, the Agency has conducted a number of activities that document the state of clinical practice in diagnostic radiology, including both medical and dental x-ray imaging. Studies have focused on specific imaging modalities, including general radiography, fluoroscopy, mammography, computed tomography, and dental imaging, providing a series of snapshots over time that permit a study of trends in the state of practice. One such effort — the Nationwide Evaluation of X-ray Trends, a collaboration begun in 1972 with the Conference of Radiation Control Program Directors — continues to this day. This presentation provides a summary of past and present radiological health activities at the Agency and discusses how those activities have contributed to broader collaborative efforts aimed at documenting and improving the quality of diagnostic x-ray practice.

2:25 pm

Mahadevappa Mahesh

Johns Hopkins University School of Medicine

Professor of Radiology and Cardiology at the Johns Hopkins University School of Medicine, Baltimore, Maryland.

Dr. Mahesh's research interests are in medical imaging, particularly in areas of computed tomography (CT), interventional fluoroscopy, and digital mammography and in the assessment of patient dose and risks from medical x-ray imaging including CT.

Dr. Mahesh is currently associate editor for the *Journal of American College of Radiology* and Consultant to the Editor for *RadioGraphics*. He serves in a number of leadership roles, including as Chair of Physics Commission and member of board of chancellors for the American College of Radiology, Treasurer and

Executive Committee member for the American Association of Physicists in Medicine, and is member of the Radiation Control Advisory Board for the State of Maryland.

Dr. Mahesh is also an NCRP Council member and served as Vice Chair for NCRP SC 4-9 that wrote NCRP Report No.184.

Medical Radiation Exposure of Patients in the United States (NCRP Report No. 184)

NCRP Report No. 160 (2009) demonstrated the rapid and dramatic increase in diagnostic and interventional patient medical radiation exposures between early 1980 up to 2006. The report led to the examination of medical radiation exposures by many groups both in the United States and internationally. NCRP Scientific Committee 4-9 formed in 2016 was charged to prepare a report to evaluate changes in medical x-ray exposure since NCRP Report No. 160. The charge to the committee was to assess the number and types of medical x-ray procedures, the average per caput and collective effective doses, and the changes since 2006. Even though NCRP Report No. 160 was published in 2009, the data were as of 2006. Similarly, the new report (NCRP Report No. 184), recently released, reports data as of 2016. From the onset, the committee members agreed to report effective dose values only for the various medical x-ray procedures and decided not to include organ doses and not include radiation therapy procedures. The publication of new tissue weighting factors (ICRP Publication 103) was accounted and the committee decided to compute collective effective doses using both ICRP Publications 60 and 103 weighting factors. This was done in order to compare the final results with those of NCRP Report No. 160 and to examine the impact of tissue weighting factors. Even though the largest contributor to collective dose among medical radiation exposure is from computed tomography, the estimated annual individual effective dose was similar to NCRP Report No. 160. Overall, the 2016 estimates for collective effective dose (S) and effective dose per capita (E_{US})

indicates a decline from 2006 by ~15 to 20 %. Details of the estimated S and E_{US} for each modality are presented and the details on how the number of procedures and the effective dose for each modality is estimated is discussed in this presentation.

2:50 pm

R. Craig Yoder

Directed Landauer's technical activities relating to radiation dosimetry, particularly for applications in radiation protection from 1983 through his retirement in 2015. Additionally, he oversaw subsidiary and partner businesses located in Australia, Brazil, China, France, Japan, Mexico, Sweden and Turkey.

An internationally known expert in radiation monitoring, Dr. Yoder led Landauer's transition from film and thermoluminescent dosimetry technology to optically stimulated luminescence, an assignment that required strategic planning and direction in areas spanning scientific research, product development, manufacturing, laboratory operations, and marketing. From 1993 to 2001, he was Vice President of Operations and managed Landauer's manufacturing and analytical laboratory activities in addition to overseeing research and development programs.

Dr. Yoder is a member of NCRP and former President of the Council on Ionizing Radiation Measurements and Standards. He has served on several national and international committees to develop dosimetry standards. He was a member of a National Research Council's committee that examined the accuracy of film badge measurements made during atmospheric nuclear weapons testing.

Estimating Lung Doses to Medical Workers in the Million Person Study (NCRP Scientific Committee 6-11)

NCRP Report No. 178 presents an 11-step process to guide the radiation dose reconstruction process to be applied to the worker groups comprising the epidemiological Million Person Study (MPS). Medical radiation workers make up a large group of individuals occupationally exposed to low doses of radiation (and are a sub-cohort of the MPS), who have been monitored with the use of personal dosimeters when potentially exposed to ionizing radiation, and the measurements have generally been maintained. For epidemiologic studies, it is often assumed that the average dose over the entire organ or tissue (organ dose) is the quantity of interest in the analysis. However, the derivation of organ doses for the medical worker cohort members from monitoring data poses difficult problems because of, among other factors: often extreme inhomogeneity of exposure over the body of personnel for any given procedure type as organs or tissues may only be partially irradiated, for example when medical personnel wear lead aprons; differing degrees and methods of radiation protection; inconsistent wearing of dosimeters by personnel (*i.e.*, at times choosing not to wear dosimeters in order to avoid investigations), combined with poor information, as well as high variability, on the workloads of physicians and technologists (*i.e.*, the number of procedures of a given type conducted monthly or annually); and changing technology and medical procedure protocols. NCRP Scientific Committee 6-11 was charged with the task of describing an optimum approach for using personal monitoring data to estimate lung and other organ doses along with specific precautions applicable to epidemiologic study of medical radiation workers, recognizing many associated uncertainties.

3:15 pm **Break**

3:45 pm

Lawrence T. Dauer

Memorial Sloan Kettering Cancer Center

Associate Attending Physicist specializing in radiation protection at MSKCC in the Departments of Medical Physics and Radiology. He is a Council and Board member of NCRP and served as a member of the ICRP Committee 3, Protection in Medicine.

Evaluation of Sex-Specific Differences in Lung Cancer Radiation Risks & Recommendations for Use in Transfer & Projection Models (NCRP Scientific Committee 1-27)

Recent results from the study of Japanese atomic-bomb survivors, exposed briefly to radiation, find the risk of radiation-induced lung cancer to be nearly three times greater for women than for men. Because protection standards for astronauts are based on individual lifetime risk projections, this sex-specific difference limits the time women can spend in space (NCRP Commentary No. 23, 2014). The National Aeronautics and Space Administration (NASA) requested that NCRP evaluate the risk of radiation-induced lung cancer in populations exposed to chronic or fractionated radiation to learn whether similar differences exist when exposures occur gradually over years contrasted with the acute exposure received by the Japanese atomic-bomb survivors. In response to NASA, NCRP initiated an epidemiologic study of ~150,000 medical radiation workers (~50 % women) and additional U.S. Department of Energy worker cohorts within the Million Person Study. These studies are viewed in the context of other studies of reasonable quality with estimates of radiation-induced lung cancer when radiation is given gradually over time (*e.g.*, studies of tuberculosis patients, indoor radon, Mayak workers, scoliosis patients). An extensive and comprehensive review is needed of all epidemiologic studies and animal experiments, as well as mechanistic models. In addition, an evaluation of the factors affecting transfer of risk modelling and incorporation within lifetime risk projection are required. NCRP is evaluating the current risk projection model used by NASA for lung cancer life-time risk projection and examine whether the new data on low dose rate exposures and sex-specific lung cancer risks will be such as to recommend modifications.

4:10 pm

Angela Shogren
U.S. Environmental Protection Agency
Public Affairs Specialist at EPA's Center for Radiation Information and Outreach. Ms. Shogren is an NCRP Council member and represents EPA as a radiation risk communication expert in a working group led by the World Health Organization.

Radiation Risk Communication in Medicine (NCRP Program Area Committee 7)
Medical professionals feel confident prescribing and performing necessary procedure for patients, but when associated radiation risks are raised, many healthcare professionals may not feel adequately prepared to address patient concerns. Effectively communicating radiation risks to patients is often an afterthought in medical education or merely touched on during general patient communication training. There are two main radiation risk communication pathways in medicine — professional-centered communication (between two or more medical professionals) and patient-centered communication (between a medical professional and a patient). There are many ways to communicate radiation risk in medicine; no “one size fits all” script, delivery, or approach. When communicating with patients or other health professionals, it’s imperative to understand the subject’s background, risk perception, and unique situation.

4:35 pm

Kimberly Applegate
University of Kentucky
Member of NCRP and on the Main Commission of the International Commission on Radiological Protection as the Chair of Committee 3, focusing on radiation protection in medicine. Dr. Applegate is a retired professor of radiology and pediatrics at the University of Kentucky in Lexington. Dr. Applegate is a leader in radiology— Dr. Applegate’s policy and research work, including 200 publications, has resulted in an improved understanding of the structure, process and outcomes of how pediatric imaging is practiced, including the volume of ionizing imaging in children, the variation in radiation dose in pediatric computed tomography, and the standardization of practice for both children and adults. She has worked collaboratively around the world to improve practice.

From its start in 2007 to the present, she has worked on the Steering Committee for the Image Gently® Campaign to improve safe and effective imaging care of children worldwide. Dr. Applegate has received a number of awards that include the 2019 American Association of Physicists in Medicine’s Honorary Membership and the American Association for Women in Radiology’s Marie Sklowdoska Curie Award for her unique roles in leadership and outstanding contributions to the advancement of women in the radiology professions.

The ICRP & Its Role in Guidance, Communication, & Collaboration
The International Council for Radiation Protection (ICRP) is an independent, not-for-profit organization with a mission to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation. Founded in 1928, it currently comprises a community of more than 250 globally-recognized experts in radiological protection (RP) science, policy, and practice from more than 50 countries. Committee 3 addresses protection of persons and unborn children when ionizing radiation is used in medical diagnosis, therapy, and biomedical research—and since 2017—protection in veterinary medicine. ICRP Committee 3 has a wide mandate in radiation protection and its members have expertise in diagnostic radiology, radiation oncology, nuclear medicine, medical physics, epidemiology and biostatistics, regulatory application of RP, process and quality improvement, and human and veterinary medicine. We work together with ICRP committees, and we collaborate with a number of organizations including radiology, medical physics, and regulatory bodies.

Discussion

5:00 pm

Kathryn D. Held
President, NCRP