Fifty-Fourth
Annual Meeting Program

Radiation Protection Responsibility in Medicine

March 5–6, 2018

Hyatt Regency Bethesda
One Bethesda Metro Center
7400 Wisconsin Avenue
Bethesda, MD 20814

NCRP
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NCRP Mission:

To support radiation protection by providing independent scientific analysis, information and recommendations that represent the consensus of leading scientists.

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Introduction

Radiation Protection Responsibility in Medicine

Fifty-Fourth Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP)

The utilization of radiation in medicine, both for imaging (especially computed tomography and molecular imaging), and for therapy, has increased significantly over the past quarter century on both a national and a global scale and has revolutionized the way we practice medicine. However, the issues of perceived, potential, theoretical and known risks associated with ionizing radiation exposure from imaging and therapy have come to the forefront of both public and professional awareness, raising concerns and controversies. There continues to be a great deal of incomplete and misunderstanding about the use of radiation in medicine, especially related to which modalities depend on ionizing radiation for study performance, radiation doses delivered and the biological consequences, especially the development of cancer, from medical imaging. Diagnostic imaging procedures using ionizing radiation carry, at most, relatively small individual risks. These potential risks are minimized by only performing imaging examinations that are justified by medical need and maximizing diagnostic yield (optimization) while minimizing potential risks. Therapies are increasingly being designed and administered so as to increase the dose to treatment areas while reducing the doses to healthy tissues.

The use of radiation in medicine that is both justified and optimized is best practice. The appropriate use of radiation in medicine has been a recognized aim since the advent of the x ray, and use has followed development of new technology and advances in existing technology, resulting in substantial increases in the contribution from medical sources to per capita U.S. exposure over the past few decades. The responses to this increased use of ionizing radiation have included improving technology and utilization, regulatory/accreditation requirements and guidance, as well as education including social media efforts and grassroots social marketing campaigns.

In 2012, the International Atomic Energy Agency and the World Health Organization held an international conference on radiation protection in medicine. The conference resulted in the "Bonn Call for Action" that suggested 10 actions to improve radiation protection in medicine in the next decade. These actions help to clarify the current challenges for continuous improvement of radiation responsibility in medicine:

1. Enhance the implementation of the principle of justification.
2. Enhance the implementation of the principle of optimization of protection and safety.
3. Strengthen manufacturers' role in contributing to the overall safety regime.
4. Strengthen radiation protection education and training of health professionals.
5. Shape and promote a strategic research agenda for radiation protection in medicine.
6. Increase availability of improved global information on medical exposures and occupational exposures in medicine.
7. Improve prevention of medical radiation incidents and accidents.
8. Strengthen radiation safety culture in healthcare.
9. Foster an improved radiation benefit-risk dialogue.
10. Strengthen the implementation of safety requirements globally.

Amongst several other important advances in comprehensive radiation protection, the National Council on Radiation Protection and Measurements (NCRP) has helped facilitate recent improvements in several of these medical areas, including: dentistry (Report No. 145), x-ray shielding (Report No. 147), mammography (Report No. 149), therapy shielding (Report No. 151), preconception and prenatal radiation exposures (Report No. 174), and guidance on radiation dose limits for the lens of the eye (Commentary No. 26). Several previous NCRP annual meetings have identified and addressed opportunities for radiation protection in medicine. In 2010, NCRP addressed the communication of radiation benefits and risks in decision making. In 2013, NCRP addressed emerging issues in radiation protection in medicine (along with emergency response and the nuclear fuel cycle). The issue of radiation responsibility in medicine has continued to evolve since. Because of the significant recent advances in the use of radiation and radioactivity in medicine as well as the concurrent increase in radiation protection and safety methods and quality systems, NCRP is devoting its annual meeting this year to this important topic.

The meeting has been divided into several topical areas that aim to explore important and relevant areas of inquiries associated with ionizing radiation dose, benefit, risk and safety; modalities including diagnostic x-ray imaging, nuclear medicine as well as radiation oncology; dialogue and shared decision making; and the fostering of innovations moving forward. Given the extensive domain that it is necessary to cover, together with mindfulness of adult learning models, a greater number of shorter and highly focused topics will be this year's model. Content will be directed to identifying recent advances and future opportunities and challenges.

NCRP and the Radiation Research Society (RRS) are pleased to welcome the NCRP/RRS Scholars to this year's Annual Meeting. The three young scientists below received competitive travel awards made possible by the generosity of RRS. These awards are aimed at encouraging and retaining young scientists in the field of radiation science. Eligible applicants included junior faculty or students in the radiation sciences or junior health or medical physicists:

- Manuela Buonanno
- James McEvoy
- Margarita Pustovalova

Questions can be submitted on cards during each session. Oral questions from the floor will not be accepted, although, as always, dialogue is both encouraged and welcomed during breaks and other time outside of the presentations. The session chairs and speakers will address as many questions as time permits. All questions and answers will be published, along with the presentations, in *Health Physics* as part of the Proceedings of the Annual Meeting.

The Fifteenth Annual Warren K. Sinclair Keynote Address will be given by Mr. Marvin Rosenstein, Distinguished Emeritus Member and Staff Consultant, NCRP. Mr. Rosenstein's presentation will provide an overview of the work of NCRP with regard to radiation protection responsibility in medicine and will set the stage for the remainder of the meeting.

The Forty-Second Lauriston S. Taylor Lecture will be delivered by Dr. Hans-Georg Menzel, Chairman, International Commission on Radiation Units and Measurements, and on the Main Commission of the International Commission on Radiological Protection. Dr. Menzel's lecture will provide an overview of radiation dosimetry for medicine and protection, especially from the European perspective.

The Second Thomas S. Tenforde Topical Lecture will be delivered by Dr. Roy Shore, Radiation Effects Research Foundation (retired) and NCRP Distinguished Emeritus Member. Dr. Shore's presentation will address the important question: Do the epidemiologic data support use of the linear nonthreshold model for radiation protection?

NCRP President, Dr. John Boice, will conclude the meeting by presenting a brief overview of recent NCRP activities and a vision for the future direction of NCRP.

NCRP is grateful to:

- the Joint Armed Forces Honor Guard from the Military District of Washington D.C. who will open our Annual Meeting;
- Kimberly Gaskins of the U.S. Nuclear Regulatory Commission who will sing our National Anthem (https://www.youtube.com/watch?v=DKTHo-saa9do);
- Major Kimberly Alston for coordinating the military volunteers; and
- Thomas E. Johnson and students from Colorado State University for recording the presentations and making them available after the meeting.

PLEASE NOTE: All areas of the meeting are being recorded and photographed. If you wish to opt-out of videos/photos please visit the registration desk. Videos will be posted on the Center for Health, Work & Environment, Colorado School of Public Health website and the photographs will be posted on the NCRP flickr account.

Monday, March 5, 2018

Opening Session

8:10 am **Presentation of the Colors**
Joint Armed Forces Honor Guard from the Military District of Washington, DC

Singing of the National Anthem
Kimberly Gaskins
U.S. Nuclear Regulatory Commission

8:15 am **NCRP Welcome**
John D. Boice, Jr.
President, NCRP

8:20 am **A Radiation Wish List from Jennifer: Gadgets, Radiation Statements, and Insta-Reports**
Kate Niehaus
Memorial Sloan Kettering Cancer Center

Fifteenth Annual Warren K. Sinclair Keynote Address

8:30 am **Jus•ti•fied and Com•men•su•rate**
Marvin Rosenstein
National Council on Radiation Protection and Measurements

Dose, Benefit, Risk and Safety

Lawrence T. Dauer & Helen A. Grogan, *Session Co-Chairs*

9:00 am **Radiation in Medicine: Current and Future Trends**
Fred A. Mettler, Jr.
University of New Mexico School of Medicine

9:15 am **Effective Dose and Alternatives**
Jerrold T. Bushberg
University of California Davis School of Medicine

9:30 am **Benefit and Risks**
Pat B. Zanzonico
Memorial Sloan Kettering Cancer Center

9:45 am **Quality and Safety Initiatives**
Mythreyi Chatfield
American College of Radiology

10:00 am **Q&A**

10:30 am **Break**

Diagnostic X-Ray Imaging

Linda Kroger & Mahadevappa Mahesh, *Session Co-Chairs*

11:00 am **Projection X-Ray Imaging (Radiography, Mammography, Fluoroscopy)**
J. Anthony Seibert
University of California Davis Health

11:15 am **Computed Tomography Technology – and Dose – in the 21st Century**
Cynthia H. McCollough
Mayo Clinic

11:30 am **Doses, Benefits, Risks and Safety in Oral and Maxillofacial Diagnostic Imaging**
Alan G. Lurie
University of Connecticut School of Dental Medicine

11:45 am **Q&A**

12:15 pm **Lunch**

Nuclear Medicine & Radiation Oncology

Polly Y. Chang & Pat B. Zanzonico, *Session Co-Chairs*

1:30 pm **Radiopharmaceutical Therapy**
George Sgouros
Johns Hopkins University School of Medicine

1:45 pm **Dose Optimization of Hybrid Imaging**
Frederic H. Fahey
Boston Children's Hospital & Harvard Medical School

2:00 pm **Radiation Oncology: External Beam Radiation Therapy**
Melissa C. Martin
American Association of Physicists in Medicine

2:15 pm **Radiation Protection Responsibility in Brachytherapy**
Bruce Thomadsen
University of Wisconsin School of Medicine and Public Health

2:30 pm **Q&A**

3:00 pm **Break**

Dialogue and Shared Decision Making

Randall N. Hyer & Julie E.K. Timins,
Session Co-Chairs

3:30 pm **Effective Stakeholder Communications Methods: The Power of Planned Persuasive Messaging**
Jessica S. Wieder
U.S. Environmental Protection Agency

3:45 pm **Patient Perspectives on Dialogue and Shared Decision Making**
Lawrence T. Dauer
Memorial Sloan Kettering Cancer Center

4:00 pm **Optimizing Patient Informed Decision Making: Examples from Pediatric and Emergency Care**
Kimberly E. Applegate
University of Kentucky

4:15 pm **Radiation Protection Responsibility in Medicine Dialogue and Shared Decision Making in Pediatric Healthcare**
María del Rosario Pérez
World Health Organization

4:30 pm **Q&A**

4:45 pm **Break**

Forty-Second Lauriston S. Taylor Lecture on Radiation Protection and Measurements

5:00 pm **Introduction of the Lecturer**
R. Julian Preston

Radiation Dosimetry Research for Medicine and Protection: A European Journey
Hans-Georg Menzel

6:00 pm **Reception**
Sponsored by Landauer, Inc.

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Tuesday, March 6

8:15 am **NCRP Annual Business Meeting**

9:30 am **Break**

Second Thomas S. Tenforde Topical Lecture

9:45 am **Do the Epidemiologic Data Support Use of the Linear Nonthreshold Model for Radiation Protection?**
Roy E. Shore

Fostering Innovations

Kimberly E. Applegate & Donald L. Miller,
Session Co-Chairs

10:15 am **Medical Physics 3.0 to Ensure Quality and Safety in Radiation Medicine**
Ehsan Samei
Duke University / American Association of Physicists in Medicine

10:35 am **Advancing Safety: Role of Equipment Design and Configuration Change**
Keith J. Strauss
Cincinnati Children's Hospital Medical Center

10:55 am **How Innovations in Computer Technologies Have Impacted Radiation Dosimetry Through Anatomically Realistic Phantoms and Fast Monte-Carlo Simulations**
X. George Xu
Rensselaer Polytechnic Institute

11:15 am **Q&A**

11:30 am **Break**

Conclusions and Path Forward

Lawrence T. Dauer & Donald P. Frush,
Session Co-Chairs

11:45 am **Radiation Protection Responsibility in Medicine: A Wrap Up**
Donald P. Frush
Duke University Medical Center

12:00 pm **NCRP Vision for the Future and PAC Activities**
John D. Boice, Jr.
President, NCRP

12:30 pm **Adjourn**

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Fifteenth Annual Warren K. Sinclair Keynote Address

8:30 am

Jus•ti•fied and Com•men•su•rate
Marvin Rosenstein
National Council on Radiation Protection and Measurements

When patients are exposed to ionizing radiation for medical diagnosis or treatment, the procedure being performed should be justified and the amount of ionizing radiation used should be commensurate with the medical purpose. Go back to the earlier and go forward to the current International Commission on Radiological Protection's and NCRP's publications … that same message is consistently found.

A legal limit on the amount of ionizing radiation used for medical exposure of a patient just does not apply. Such a limit would do more harm than good. There are suspected or existing chronic, severe, or even life-threatening medical conditions that are more critical than the radiation exposure. Each iteration of patient exposure is a separate assessment (be it informal or formal) to satisfy that the benefit to the patient outweighs any associated radiation-related impact. There are unique aspects of the medical exposure of patients: the exposure to ionizing radiation is deliberate for an intended outcome; and the acceptance of the exposure is voluntary with the expectation of direct individual health benefit to the patient exposed.

The biological basis for radiation protection of patients is the same as for all other ionizing radiation exposures:

- Tissue reactions (deterministic effects) occur if the radiation dose to tissue is above some threshold, as can happen during radiation therapy or complex fluoroscopically guided interventional procedures. These effects should be prevented, avoided, or when clinically unavoidable should be carefully managed.
- There is an increased overall probability of cancer (in a number of different organs and tissues) occurring in an exposed population above the baseline incidence of cancer in the general population:
  - that increased probability is nonuniformly distributed: some patients are examined much more frequently due to their health status; some groups show higher than average sensitivity for cancer induction [*e.g.*, the embryo-fetus, infants, young children, young females (breast cancer)];
  - at mean absorbed doses in organs and tissues above ~100 mGy, the increased probability in a population is generally accepted from the collective epidemiologic evidence, but the dose response is not unique for all genders, ages, tissues and organs;
  - at 100 mGy and below it has not yet been feasible to determine if there is or is not such an increased probability, and the alternative dose-response relationships have been long debated;
  - but, given the increased probability of cancer at mean absorbed doses in organs and tissues above ~100 mGy, and that organ or tissue doses accumulated from medical exposures to a given individual over time often exceed 100 mGy, it is prudent to properly manage organ and tissue doses to all patients at all times.

Justifying the clinical procedure, as (1) being appropriate for the clinical purpose, and as (2) being appropriate for an individual patient, is in the purview of the clinical community and individual practitioners, respectively. Significant efforts have been made to produce and implement such clinical guidance. A brief commentary on such efforts will be included.

Managing ionizing radiation levels to be commensurate with the medical purpose is becoming a more prominent feature for all types of imaging procedures (to manage the increased probability of cancer). An approach called *diagnostic reference levels* is finding widespread use throughout the world. A diagnostic reference level is a method for evaluating whether the amount of radiation is unusually high or low for a particular imaging procedure. If so, the reasons for that observation should be investigated. This is an advisory tool … remember legal limits are just not appropriate. The point … if you know how much radiation is actually being used, you can evaluate if that amount is appropriate for the clinical task. If you do not know the amount … well, you do not know if the amount used is appropriate. The current advice for application of diagnostic reference levels in medical imaging will be presented.

In summary (again): the clinical radiological procedure should be *Jus•ti•fied* for the individual patient, and the ionizing radiation level for the procedure should be *Com•men•su•rate* with the medical purpose.

Dose, Benefit, Risk and Safety

Lawrence T. Dauer & Helen A. Grogan, *Session Co-Chairs*

9:00 am

Radiation in Medicine: Current and Future Trends

Fred A. Mettler, Jr.
University of New Mexico School of Medicine

National Council on Radiation Protection and Measurements' Report No. 160, *Ionizing Radiation Exposure of the Population of the United States* (2009), assessed the nonoccupational radiation exposure to the U.S. population from medical exposures up until 2006. Scientific Committee (SC) 4-9 is now in the process of updating that information with data from a number of sources and will estimate the number and types of procedures as well as the collective and *per caput* effective dose. Some of this is complicated by the change in the International Commission on Radiological Protection tissue weighting factors in 2007 and the use of more complex computational phantoms. Over the last decade there have been significant technical, procedural and economic changes in the imaging and therapeutic landscape. There has also been a concerted effort to develop appropriateness and other guidelines to optimize dose and ordering. There has been essentially a complete transition from film-screen receptors to digital and solid-state systems. In radiography essentially all images are computed radiography or digital radiography and the total number of radiographs has declined slightly. In mammography all images are digital and there has been the rapid emergence of tomosynthesis (three dimensional) which is rapidly gaining in clinical use. Traditional noninterventional fluoroscopic studies (such as upper gastrointestinal and barium enema) have declined markedly with replacement predominantly by fiber-optic endoscopy. Diagnostic and interventional fluoroscopically guided cardiac procedures have changed with more combined diagnostic and therapeutic coronary studies and the development of structural cardiac imaging. Data for interventional radiology has proven to be more difficult to assess as the procedures have become more complex and they are carried out in multi-use suites used by cardiologists and vascular surgeons.

Computed tomography (CT) scanning increased from 2006 to about 2012 and since then has leveled off with most equipment being multidetector very fast scanners. So-called *cone-beam CT* is in use for interventional procedures, dental examinations, and a wide variety of other uses. Dental imaging has become more complex with some machines now having combined panoramic, cephalometric, and cone-beam CT capabilities. Nuclear medicine has undergone marked decline in the number of overall procedures since about 2009 but with about half still being cardiac. The number of hybrid positron emission tomography and single-photon emission CT studies has increased significantly. In radiation oncology there are many different imaging methods that have emerged for treatment planning and even four-dimensional imaging during the treatment. The quantitative aspects and estimates of procedure frequency, dose, etc. will be included in the forthcoming SC 4-9 report.

9:15 am

Effective Dose and Alternatives

Jerrold T. Bushberg
University of California Davis School of Medicine

Effective dose (*E*) is internationally accepted and applied as a central radiation protection quantity in a system for radiological protection developed the by the International Commission on Radiological Protection (ICRP). *E* and its predecessor (effective dose equivalent) were initially developed to solve the conceptual and practical problem of administratively accounting for and controlling the dose from internally deposited radionuclides and external radiation exposure. *E* considers detriment (harm) from stochastic effects (primarily cancer mortality and morbidity) of radiation exposure. It does not include tissue reactions which occur at higher doses and for which there is a threshold dose, below which damage does not occur. The qualifier "effective" before the word dose is used to denote that this quantity with units in sievert is in fact, not a radiation dose in the same way that absorbed dose (units of gray) is. *E* is a mathematical construct used in radiation protection, not a real radiation dose to a specific person, rather it is surrogate representing an approximate stochastic risk applied to a standardized model. In deriving *E*, mean tissue weighting values are utilized, which are chosen to roughly account for different sensitivities of different organs and tissues to the induction of stochastic effects of radiation. The rounded values for all tissues sum to unity and are assigned by an expert panel representing values applied to a hybrid reference population of both sexes and all ages. Consequently, *E* does not relate to the characteristics of any specific individual or even specific population; also, it does not include any estimate of uncertainty. *E* is primarily used retrospectively for regulatory purposes, for demonstrating compliance with dose limits and constraints. However, *E* can be used prospectively for planning and optimization of occupational and public exposure to external sources and internal emitters.

As discussed in numerous publications of the United Nations Scientific Committee on the Effects of Atomic Radiation, ICRP, and NCRP, risks associated with medical procedures are best evaluated using appropriate risk values for the individual tissues exposed and for the age and sex distribution of the individuals undergoing the medical procedures. ICRP has repeatedly emphasized that *E* was not intended, nor should it be used as a quantitative predictor of any stochastic risks from radiation exposure. This is especially true for predicting cancer incidence or mortality from diagnostic imaging procedures where the effective doses are small (<10 mSv) and the population exposed is large. Nevertheless, *E* is often, inappropriately, used in medical literature as a surrogate for whole-body dose from diagnostic x-ray procedures. In its most egregious form, this dose is used to calculate estimates of cancer incidence and mortality in large populations of past or future patients.

Alternatives to *E* have been proposed such as "effective risk" which attempt to account for differences in sensitivity to radiation as a function of age and sex. Others have made arguments for using *E* as a general indicator (*i.e.*, order of magnitude) for communicating radiation risk to patients and research subjects exposed during diagnostic and interventional procedures, if its limitations are kept in mind. The attraction to the use of *E* for all things dose related is that it is easy to understand. It provides a single metric that is widely used (appropriately or not) for comparison of stochastic radiation risk from such disparate sources of exposure as medical imaging, occupational and public domains, natural background and population exposures from accidental environmental releases of radioactivity. There are methods for estimating *E* from computed tomography (from dose-length product), x-ray projection imaging (from kerma area product), and nuclear medicine procedures (from administered activity). However, even the most liberal users of *E* would agree that there are some situations (*e.g.*, radiation therapy or single organ dose diagnostic exams such as mammography) for which the use of *E* is clearly inappropriate.

9:30 am

Benefit and Risks

Pat B. Zanzonico
Memorial Sloan Kettering Cancer Center

The introduction of ionizing radiation in the healing arts revolutionized the diagnosis and treatment of disease and dramatically improved the quality of healthcare. In recent years, however, concern over the radiogenic risks associated with medical imaging has grown considerably, fueled by widespread attention in both the scientific and lay media. Such concern is beneficial in terms of promoting critical evaluation of imaging procedures, with technical optimization, elimination of truly unnecessary procedures, and minimization of imaging doses without compromising the diagnostic information being sought. However, consideration of radiogenic cancer risk, sometimes couched in spectacular terms, can create the detrimental misconception that radiation is the *only* risk to be considered in medical imaging. Although the point is often made that the benefits of radiation in medicine are much greater than any theoretical risks, *quantitative* estimates of the benefits are not juxtaposed with quantitative estimates of risk. This alone — expression of benefit in purely qualitative terms versus expression of risk in quantitative, and therefore seemingly more certain, terms — may well contribute to a skewed sense of the relative benefits and risks of diagnostic imaging among healthcare providers as well as patients. This presentation, therefore, quantitatively compares the benefits of diagnostic imaging in several cases, based on actual mortality or morbidity data if ionizing radiation were not employed, with the linear nonthreshold model-derived (*i.e.*, theoretical) estimates of radiogenic cancer mortality, thus illustrating the very large benefit-to-risk ratios typical of diagnostic imaging studies.

9:45 am

Quality and Safety Initiatives

Mythreyi Chatfield
American College of Radiology

The purpose of this talk is to outline some of the existing quality and safety initiatives that support radiation protection in medicine, specifically in diagnostic imaging procedures that use ionizing radiation.

A patient's encounter with diagnostic imaging starts with consideration of appropriateness of imaging for a particular clinical indication ("justification"). Evidence based referral guidelines developed by radiologists and other physician organizations, such as the American College of Radiology (ACR) Appropriateness Criteria, guide referring physicians and patients in making informed decisions about obtaining the right imaging exam based on benefits and risks, and avoiding unnecessary imaging. Choosing Wisely® reinforces the use of guidelines with lists supported by a variety of specialty societies; all the lists call to the professionalism of ordering physicians and challenges them to reduce unnecessary testing. Similar guidelines rate appropriateness of interventional procedures based on clinical presentation.

Once the decision to image has been made, appropriate protocols and technique adjustments enable dose optimization. The American Association of Physicists in Medicine, in collaboration with other professional organizations and manufacturers, develops and publishes protocols to support this activity. Practice parameters, technical standards, and other guidelines published by specialty societies define recommended conduct in an area of clinical practice to ensure safe and high-quality imaging. Imaging accreditation programs evaluate practices for adequately trained personnel, image quality, appropriate use of radiation dose, and relevant policies and procedures. Dose index registries allow monitoring of radiation indices in practice and support improvements in dose optimization by providing comparisons to peer facilities and national diagnostic reference levels. The ACR registry currently monitors data on computed tomography (CT) dose indices and is in pilot for fluoroscopy. Local registries are used by a number of facilities that may cover conventional/digital radiology and nuclear medicine. The Image Gently® Alliance provides tools and resources for radiology practices to implement radiation protection activities for pediatric imaging. Image Wisely® offers tools and educational opportunities for radiation protection for adult patients.

Legislative initiatives, such as the Medical Imaging and Technology Alliance Smart Dose Standard (NEMA XR-29) for CT, encourage the use of equipment that provide radiation dose structured reports so that dose indices may be easily shared with registries and included in patient records. This serves to raise radiologists' awareness of radiation exposure to the patient. For procedures and imaging using fluoroscopy, a Centers for Medicare and Medicaid Services quality measure encourages documentation of radiation dose indices in the patient report. On the report, appropriate follow-up recommendations on findings, incidental findings in particular, ensure that patients are only subjected to follow-up imaging and associated radiation exposure if there is evidence or expert guidance supporting the need for that follow-up image. Peer-learning initiatives may include feedback on appropriateness of radiation exposure.

It is well recognized that medical imaging with ionizing radiation contributes to optimum healthcare and saves lives. However, as patients and physicians become more aware of the importance of radiation protection, the market place continually develops and sells new tools to practices. The role of professional societies and expert organizations is to guide practices in using them appropriately.

10:00 am **Q&A**

10:30 am **Break**

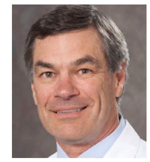
Diagnostic X-Ray Imaging

Linda Kroger & Mahadevappa Mahesh, *Session Co-Chairs*

11:00 am

Projection X-Ray Imaging (Radiography, Mammography, Fluoroscopy)

J. Anthony Seibert
University of California Davis Health



Projection x-ray imaging technology used for medical diagnosis continues to evolve, chiefly for the detector components of the system. Film-based detectors, used for over a century, are now only described in history books. Computed radiography passive detectors, the initial digital substitute for film, are being phased out, and image intensifiers, used for fluoroscopic dynamic imaging, are being replaced — in both cases by flat-panel x-ray detector implementations. This migration to active acquisition and immediate image display has several implications described in the presentation. There are many enhanced capabilities, but also introduction of problems that do not have (as yet) defined solutions.

Enhancements:

- *Workflow efficiency* is drastically improved for radiography and mammography with the elimination of labor-intensive handling of cassettes and minute-long processing time required by passive detectors.
- *Operational flexibility* is enhanced by using wireless detectors that can be freely positioned, and by not having to use an anti-scatter grid in systems with special image post-processing scatter removal techniques.
- Radiographic *image quality* is more consistent due to built-in image preprocessing and scaling algorithms. Geometric distortions caused by image intensifiers are eliminated with flat-panel detectors, and recent high-gain, low-noise flat-panel electronics for real-time imaging demonstrate excellent performance at low dose-rate levels.
- Reduction of *anatomic superimposition* in mammography and radiography is made possible by rapid image capture and storage of images at various projection angles, with reconstructed digital tomograms synthesized to produce in-focal planes. Dual energy (switched x-ray beam energy) or future photon-counting, energy-sensitive detectors can provide the means to decompose the image information into material basis sets (*e.g.*, soft tissue and bone) to assist in diagnoses.
- *Radiation dose* levels for radiography, mammography and fluoroscopy can be substantially lower, directly related to improved detector quantum efficiency.

Problems:

- Uncoupling of the radiation dose and the image appearance can lead to unknown patient radiation dose (mostly overexposures).
- Diagnostic reference level guidance is inadequate and dependent on technology (*e.g.*, conventional versus digital radiology). Image protocols on radiographic units are not consistently evaluated.
- *Radiation dose metrics* for manufacturers are widely different; meanwhile, the International Exposure Index Standard (IEC 62494-1) is slow to be adopted.
- Retake analysis, a common practice with screen-film radiography, is not adequately performed today by most users, because of inefficient

- extraction, compilation and analysis of data and lack of standards that can assist in retrieving such data.

NCRP can play a significant role in providing relevant guidance on radiation dose management in digital projection radiography to address known deficiencies and problems.

11:15 am

Computed Tomography Technology – and Dose – in the 21st Century

Cynthia H. McCollough
Mayo Clinic

In the last decade, a number of disruptive technological advances have taken place in computed tomography (CT) imaging, bringing to bear new clinical applications for the benefit of patient care. Some of the most significant advances include dual-source CT, wide-coverage or volume CT, dual-energy or spectral CT, and photon-counting-detector CT. With dual-source and volume CT technologies have come unprecedented exam speed, both in terms of conventional head or body imaging and in terms of cardiac imaging. With dual-energy and spectral CT have come completely new capabilities, including material differentiation and material quantification. Examples of material differentiation include differentiation of uric acid urinary stones from nonuric-acid stones and gout from pseudo gout. Examples of material quantification include the ability to quantify the concentration of iodinated contrast material present in tissue, organs or vessels. In addition, virtual mono-energetic images can be produced that allow amplification of iodinated contrast signal or reduction of metal artifacts. Other applications of dual-energy or spectral CT include the ability to subtract signal from a given material, creating virtual noncontrast or noncalcium images, in which iodine or calcium signal is removed, respectively. While there are a number of approaches to acquiring dual-energy CT data, the ability to acquire more than two energy data sets requires a new type of CT detector technology, referred to as photon-counting detectors. These detectors are already in use on humans in research applications and in addition to enabling fully simultaneous multi-energy data acquisition and separation of multiple k-edge contrast agents, offer reduced beam hardening and electronic noise, as well as increased spatial resolution.

Meanwhile, CT dose management technology and strategies continue to evolve, with automatic exposure control technology extending from tube current modulation to automatic optimal tube potential selection. Once a topic of research teams willing to spend hours to reconstruct a single case, iterative reconstruction techniques have become mainstream, as have image-based methods of reducing image noise; both techniques enabling reduction in dose for high-contrast applications (their utility in low-contrast tasks is more limited). With this ever-changing landscape of dose reduction strategies, it has become more complex to determine appropriate doses for specific diagnostic tasks and patient populations. Diagnostic reference levels have become a more familiar topic to clinical practices, with more U.S.-based data becoming available, in large part due to the efforts of the American College of Radiology CT Dose Index Registry. This has led to a number of promising dose-reduction trends. In addition, studies to determine the diagnostic performance as dose is reduced are becoming more numerous, giving the community outcome-based information on which to base dose reduction decisions.

In addition, CT dose reduction resources are now available from many sources, including the American Association of Physicists in Medicine and manufacturers of dose monitoring or protocol review software. These resources allow users to manage the dose from CT such that the clear clinical benefits can be achieved without compromising patient safety.

11:30 am

Doses, Benefits, Risks and Safety in Oral and Maxillofacial Diagnostic Imaging

Alan G. Lurie
University of Connecticut School of Dental Medicine

Doses, benefits and safety in oral and maxillofacial radiology (OMFR) are well known and published. Doses range from low to very low, benefits to patients can be immense, and safe techniques are well known but, sadly, widely ignored. Risks, especially to patients, have long been and continue to be controversial, due to uncertainties in low dose risk estimation.

Doses range from very low with properly executed intraoral, cephalometric and panoramic imaging to as high or higher than multidetector computed tomography (MDCT) for cone-beam computed tomography (CBCT). Intraoral imaging when executed ideally delivers doses of 5 μSv for a bitewing to 17 μSv for a full-mouth series but can be as high as 50 and 388 μSv, respectively, for these exams when rectangular collimation and fastest receptors are not used. Panoramic imaging doses range from 9 to 24 μSv, while cephalometric imaging from 2 to 6 μSv. CBCT has a wide range of doses, depending on the field-of-view (FOV) and presets used. Small FOVs range from 19 to 652 μSv, while large FOVs range from 68 to 1,073 μSv.

Benefits of OMFR are substantial when selection criteria and proper acquisition techniques are used. Dental disease, often obscured from direct vision by size and anatomy, can pose a mortal threat to the patient if undetected. Additionally, imaging is essential in planning dental implant placement, exodontia, orthodontic treatment, root canal therapy, and orthognathic surgery, to name a few applications.

Safe management of imaging in the dental environment is straight-forward; the means for minimizing dose and maximizing diagnostic efficacy have been widely and inexpensively available for decades. Rectangular collimation, fastest image receptor, thyroid shielding for children and selection criteria reduce patient dose by some 80 % over traditional techniques but are little used, although digital intraoral imaging has helped. Panoramic equipment has long been available with digital receptors that reduce doses substantially. For CBCT imaging, selection criteria are critical in defining appropriate FOVs and presets; several published papers and sections in textbooks address this but there is also published material which advocates less-than-safe use of this relatively new imaging modality.

It is treacherous to talk about risk in OMFR. Arguments over risk from diagnostic imaging have continued for over a century. Critical to this discussion is the enormous number of x-ray examinations done in U.S. dental offices; between one and two billion annually, the majority (about one billion) being intraoral examinations with steady increases in panoramic and CBCT examinations. An 80 % reduction in average dose/intraoral image would result in a population dose reduction of thousands of sievert. While radiation carcinogenesis due to conventional examinations is unlikely, large FOV, high-resolution preset CBCT examinations can be comparable in carcinogenesis risk to that of craniofacial MDCT. The uncertainty in risk estimation from diagnostic imaging doses, coupled with the huge number of dental images taken annually, and the rapid growth of CBCT imaging, dictate that safety in oral and maxillofacial imaging must be taken seriously in the interests of patients, staff, and members of the public. Following the "as low as reasonably achievable" principle and the linear nonthreshold modeling of risk continue to be prudent and appropriate.

11:45 am **Q&A**

12:15 pm **Lunch**

Nuclear Medicine & Radiation Oncology

Polly Y. Chang & Pat B. Zanzonico, *Session Co-Chairs*

1:30 pm

Radiopharmaceutical Therapy

George Sgouros
Johns Hopkins University School of Medicine

Radiopharmaceutical therapy (RPT) involves the use of radionuclides that are either conjugated to tumor-targeting agents (*e.g.*, nanoscale constructs, antibodies, peptides, and small molecules) or that concentrate in tumors through natural physiological mechanisms that occur predominantly in neoplastic cells. In the latter category, radioiodine therapy of thyroid cancer is the prototypical and most widely implemented RPT. In the category of radionuclide-ligand conjugates, antibody and peptide conjugates have been studied extensively. The efficacy of RPT relies on the ability to delivery cytotoxic radiation to tumor cells without causing prohibitive normal tissue toxicity. After some 30 y of preclinical and clinical research, a number of recent developments suggest that RPT is poised to emerge as an important and widely-recognized therapeutic modality. These developments include the substantial investment in antibodies by the pharmaceutical industry and the compelling rationale to build upon this already existing and widely-tested platform. In addition, the growing recognition that the signaling pathways responsible for tumor cell survival and proliferation are less easily and durably inhibited than originally envisioned has also provided a rationale for identifying agents that are cytotoxic rather than inhibitory. A number of radiopharmaceutical agents are currently undergoing clinical trial investigation; these include beta-particle emitters such as ^{177}Lu that are being used to label antisomatostatin receptor peptides for neuroendocrine cancers and also prostate-specific membrane antigen targeting small molecules for prostate cancer. Alpha-particle emitting radionuclides have also been studied for RPT; these include ^{211}At for glioblastoma, ^{225}Ac for leukemias and prostate cancer, ^{212}Pb for breast cancer, and ^{223}Ra for prostate cancer. The alpha emitters have tended to show particular promise and there is substantial interest in further developing these agents for therapy of cancers that are particularly difficult to treat.

1:45 pm

Dose Optimization of Hybrid Imaging

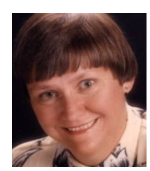
Frederic H. Fahey
Boston Children's Hospital & Harvard Medical School

Hybrid imaging combines the functional and molecular imaging of positron emission computed tomography (PET) and single-photon emission computed tomography (SPECT) with the anatomical information available from computed tomography (CT) and magnetic resonance (MR) imaging. As a result, the clinical utility of PET/CT and SPECT/CT has been clearly established in the past 17 y. In addition, the use of PET/MR which was introduced to the clinic in the past decade has continued to grow. These multi-modality approaches to medical imaging have substantial dosimetric aspects associated with their practice in both adults and children. For PET/CT and SPECT/CT, one must consider the radiation dose delivered from both the radiopharmaceutical and the CT portion of the hybrid scan. Whether the CT is to be used solely for attenuation correction, anatomical correlation of patient, or full diagnosis must be taken into account when deciding on the CT acquisition parameters. Even after 17 y, the most appropriate approach to the acquisition of these modalities is not fully established. When appropriately used PET/MR provides the opportunity for notable dose reduction. In addition to the elimination of the radiation dose from the CT, one may consider the higher sensitivity of the PET component relative to that used in PET/CT and the longer acquisition time to reduce the amount of administered activity of the radiopharmaceutical. However, one must realize that MR presents a different set of safety concerns outside of that associated with ionizing radiation. As with all medical procedures, the benefits as well as the potential risks of the procedure need to be evaluated in the context of choosing the most appropriate procedure to be performed and the optimization of acquisition protocol to assure high-quality clinical information with the least potential for risk possible.

2:00 pm

Radiation Oncology: External Beam Radiation Therapy

Melissa C. Martin
American Association of Physicists in Medicine



The application of the structural shielding design techniques and goals as outlined in NCRP Report No. 151, *Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities* (2005), continues to be the basis for treatment vault design in 2018 with some updated information. Treatment techniques have changed significantly with the dominant usage of intensity modulated radiation therapy (IMRT) techniques today based on concurrent imaging. Some of the developments in linear accelerator technology over the past 15 y include: flattening filter-free modes which enable higher instantaneous dose rates, three-dimensional conformal radiation therapy resulting in potentially higher workloads since healthy tissue is spared, improved IMRT treatment delivery systems with lower monitor units per centigray delivered than traditional step and shoot IMRT, stereotactic body radiation therapy with higher treatment fractions and increased workloads, and increased use of stereotactic radiosurgery with conventional linear accelerators as well as robotic arm mounted linacs with higher treatment fractions. These new treatment units also incorporate multiple energy x-ray beams (2 to 5 MV typical) which require a significant change in the specification of a workload to be used in each vault.

As the equipment in radiation oncology departments has evolved to state-of-the-art modalities, the requirements for adequate radiation shielding for these modalities has become more rigorous. Architectural designs no longer depend on standard maze design rectangular rooms. Innovative layouts and utilization of multiple layers of shielding materials allow much greater flexibility in room designs. Mazeless rooms with direct shielded doors are part of these challenging designs and are very common today. Use of multiple density concrete blocks allows quicker construction of vaults and requires less space for the equivalent shielding provided. Combinations of high density or normal density concrete, steel and lead are used in designs to make optimum use of available space and cost. Additional shielding needed at the edges of these single or bi-parting sliding doors as well as baffle designs for heating, ventilation, and air conditioning systems and communication cable penetrations require detailed calculations. Examples of these designs will be given in this presentation. Consideration of the radiation levels around the planned vault must also include adjacent multi-story buildings. Skyshine and ground-shine calculations will be covered to complete the presentation.

2:15 pm

Radiation Protection Responsibility in Brachytherapy

Bruce Thomadsen
University of Wisconsin School of Medicine and Public Health

Radiation protection in brachytherapy entails protecting members of the public, radiation professionals, and the patient from unnecessary radiation, as well as making sure that the radiation used in the patient's treatment is placed correctly with the correct dose distribution.

Protecting members of the public from radiation emanating from brachytherapy sources implanted in a patient was an issue several decades ago, but with modern brachytherapy, the problem has mostly disappeared. The most frequent treatments are either low-dose-rate, permanent implants for prostate cancer, or high-dose-rate (HDR) procedures for gynecological, breast or skin cancers. Almost all current permanent implants use low-energy photon sources that are shielded by the patient. Similarly, some temporary implants, such as eye-plaques that also use low-energy photon sources, incorporate a metallic shield into the applicator. All HDR brachytherapy takes place in a treatment vault, in a manner similar to external-beam radiotherapy, thus eliminating exposure to members of the public, in the absence of some terrible error or mistake.

Modern brachytherapy techniques either eliminate or greatly reduce radiation exposures to the brachytherapy staff also. As noted above, HDR treatments take place in a heavily shielded vault and staff remain outside the vault when the source is out of its shielded housing. For low-energy, permanent implants, facilities often order the sources loaded into the implant needles by the vendor, reducing the time the procedure staff is exposed to the source. Often, the loaded needles can be shielded while awaiting implantation. Alternatively, individual sources may be placed using a special applicator that shields the staff.

Radiation protection of the patient in many respects differs little from how it was decades ago except for greatly increased precision. Assaying the strength of a source of any kind is still essential. As important as verifying the source strength is ensuring that the source will be in the correct location for the desired time. Imaging serves as the main mechanism to guide the implantation and verify source or applicator position. Modern imaging has unveiled anatomy exquisitely and often permits definition of target disease and neighboring normal structures sufficiently to allow very conformal dose distributions.

Despite these great advances and capabilities, errors and mistakes (together called *failures*) still occur. Failures in healthcare overall is the third leading cause of death in the United States. Most treatment failures result not from equipment problems, but procedures gone wrong. Attention to comprehensive commissioning of both equipment and procedures, and risk-based development of quality management procedures helps protect the patient. Patient safety organizations, established by the Agency for Healthcare Research and Quality, work with client facilities to help identify weaknesses in both treatment procedures and quality management, and develop improvements to enhance protection.

2:30 pm **Q&A**

3:00 pm **Break**

Dialogue and Shared Decision Making

Randall N. Hyer & Julie E.K. Timins, *Session Co-Chairs*

3:30 pm

Effective Stakeholder Communications Methods: The Power of Planned Persuasive Messaging

Jessica S. Wieder

U.S. Environmental Protection Agency

Can 21st century radiation professionals learn from an ancient Greek philosopher? Undoubtedly, yes. Aristotle's *Rhetoric* is still considered one of the influential works on persuasive messaging. He puts the onus of effective communications on the people with the "true" and "just" information to communicate that information clearly to the audience. As members of the radiation community, it is our responsibility and duty to communicate radiation protection information successfully to stakeholders. Together, we must first recognize that, in order to create planned persuasive messages that communicate radiation information in a meaningful manner, we must adapt our communication style to meet the needs of each type of recipient, from scientists to concerned citizens, from doctors to first responders, and beyond.

3:45 pm

Patient Perspectives on Dialogue and Shared Decision Making

Lawrence T. Dauer
Memorial Sloan Kettering Cancer Center

As public awareness of medical radiation exposure increases, there has been heightened awareness among patients and physicians of the importance of holistic benefit-and-risk discussions in shared medical decision making. Often, just the mention of the word "radiation" evokes fear in patients, families, and even healthcare professionals. Communicating benefits and risks in a comprehensible manner while presenting and discussing complex technical material with associated uncertainties is a challenge that, if not performed well, could result in potential harm if patients avoid appropriate and medically necessary imaging because of misunderstanding or unfounded fears. It is important to recognize the psychological aspects of radiation risk communication, including: affect and reason, anxiety and decision making, dread from unknown hazards plus outrage, anticipated regret and side-effect aversion, information source perceptions, competence and care issues. Typically, one-sided, medical radiation risk communication methods are employed, such as paternalistic, risk numerology, and quality "assurance" approaches. But how often do we query patients themselves about what and how they want to communicate on these topics?

Patient perspectives on medical imaging radiation use is understudied, but could guide primary-care discussions. For example, when patients in a cancer-care setting were queried in facilitated focus group sessions on their knowledge, information sources, perspectives, and preferences for communication of medical imaging risks, several interesting results emerged. Although they were aware of the long-term risk of cancer from exposure to ionizing radiation, most healthcare providers did not initiate discussions about benefits and risks of radiation from imaging tests. Most patients obtained information by means of self-directed internet searches (although recent studies have questioned the accuracy of such available information). Many patients expressed gratitude for such tests (for ultimately helping to save lives), yet also expressed concern about having to initiate discussions on associated risks. On the whole, patients believed that such information should be available routinely and that conversations with their personal physician (although previous and recent studies have suggested a lack of radiation dose and risk information by physicians) or endorsed, readily available reference materials were ideal methods for information exchange.

The prevalence and correlates of worry about the health harms of medical imaging radiation (MIR) in the wider general public were also recently examined with a cross-sectional, nationally representative sample ($N = 3{,}532$) study using information from the 2012 to 2013 Health Information National Trends Survey conducted by the National Cancer Institute. Approximately 65 % of the sample population reported experiencing at least some worry about MIR (similar to concerns associated with chemicals in household products, indoor air contaminants, and chemicals in personal products). Higher rates of worry about MIR were identified among women, racial/ethnic minorities, those with lower educational attainment, foreign-born Americans, those who self-report poorer health, and those with a personal history of cancer. Lower trust in cancer information from physicians and greater attention to cancer information from popular media were each associated with higher rates of worry about health harms of medical imaging radiation. It appears that worry about MIR is relatively high in the U.S. population, and highest in the underserved, those with health challenges, those who are less trusting of cancer information from their physicians, and those more attentive to cancer topics in the media.

When combined, these findings suggest a substantial gap still exists between public and patient expectations and current medical practices.

4:00 pm

Optimizing Patient Informed Decision Making: Examples from Pediatric and Emergency Care

Kimberly E. Applegate
University of Kentucky

There are a number of opportunities for the radiology community to build on its existing radiation protection and risk communication knowledge. This presentation provides both scenarios and research approaches from the pediatric and emergency medicine communities on benefit-risk discussions about ionizing imaging examinations that may be adapted by radiology for dialog with patients, carers, and other healthcare practitioners.

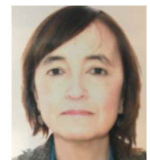
Patient-centered emergency diagnostic imaging relies on efficient communication and multispecialty care coordination to ensure optimal imaging utilization. The construct of the emergency diagnostic imaging care coordination cycle with three main phases (pretest, test, and post-test) provides a useful framework to evaluate care coordination in patient-centered emergency diagnostic imaging. Multiple factors contribute to suboptimal use of medical imaging in the emergency department (ED), with attendant patient adverse events, including risk of contrast-induced nephropathy and *ionizing radiation exposure*, increased ED lengths of stay, and healthcare costs. Barriers in communication between the patient and clinicians include but are not limited to incomplete historical data, failure to transfer or review imaging in a timely fashion, and a need for structured reporting and follow-up of critical diagnostic findings. Efficient, two-way communication of accurate and relevant patient-care information is critical for the provision of high-quality patient care. Ideally, a diagnostic imaging "closed-loop" cycle would be initiated by the physician (*e.g.*, with physician order entry systems, supplemented by decision support algorithms) and the loop completed with timely communication of imaging findings.

This presentation suggests lessons from the pediatric and emergency medicine communities and examples of collaborative approaches to dialog and shared decision making in benefit-risk conversation within the radiology community. The research focus within the emergency medicine community for *optimizing diagnostic imaging* includes (1) defining component parts of the emergency diagnostic imaging care coordination process, (2) identifying gaps in communication that affect emergency diagnostic imaging, and (3) defining optimal methods of communication and multidisciplinary care coordination that ensure patient-centered emergency diagnostic imaging.

Diagnostic imaging is integral to the evaluation of many ED patients. However, relatively little effort has been devoted to patient-centered outcomes research in emergency diagnostic imaging. What is most important to patients, caregivers, and other key stakeholders and which methods will most optimally engage patients in the decision to undergo imaging. Case vignettes can be used to emphasize these concepts as they relate to a patient's decision to seek care at an ED and the care received there. The presentation will define patient-centered outcomes as stated by the Patient-Centered Outcomes Research Institute and distinguish these from patient-reported outcomes.

4:15 pm

Radiation Protection Responsibility in Medicine Dialogue and Shared Decision Making in Pediatric Healthcare



María del Rosario Pérez
World Health Organization

The medical use of ionizing radiation in children has rapidly increased during the past two decades: digital imaging is replacing conventional film-based radiography, providing images that are instantly available for analysis and electronic distribution, with lower costs and facilitated access; computed tomography (CT) became an essential tool for assessing pediatric illness and injury; image-guided interventional radiology can now replace more complex pediatric surgery options; dental cone-beam CT is increasingly used to obtain three-dimensional views in children; nuclear medicine and hybrid imaging techniques provide functional information for the diagnosis, staging, treatment and follow-up of a variety of pediatric disorders and radiotherapy is a key component of the management of many pediatric tumors. The clinical value of the use of radiation in pediatric healthcare is unquestionable: it saves lives. However, inappropriate or unskilled use of such technologies may result in unnecessary exposures that may increase risk and provide no added benefit to pediatric patients. Patients and families should be part of risk-benefit discussions so they can understand the information and use it for making informed decisions. If they are not properly informed, they may make choices that are not beneficial and may be even harmful (*e.g.*, to refuse a procedure that is needed or to demand another one which is not justified). Healthcare providers requesting and/or performing radiological medical procedures in children have a shared responsibility to communicate radiation risks to patients, parents, and other caregivers. Both patients and parents have the right to accept or object to the procedure. The informed decision-making process in pediatric healthcare includes the (explicit or implied) consent of the parents, as well as the child's capacity to assent. The assent and consent processes should be the result of an ongoing, interactive conversation with the child and caregivers which provides age-appropriate information to help them understand the nature of the examination and its importance for their medical care, taking into account literacy level, native language, language fluency, and cultural aspects. In emergency situations, although there may not be time to obtain consent or assent (*e.g.*, immediate need to perform life-saving procedures), information has to be provided retrospectively. Integrated people-centered health services represent a fundamental change in the way health services are funded, managed and delivered, shifting away from health systems designed around diseases and institutions towards health systems designed for people. People-centered care adopts individuals', carers', families' and communities' perspectives as participants in, and beneficiaries of, trusted health systems that are organized around the comprehensive needs of people rather than individual diseases: it means care that is delivered in an equal and reciprocal relationship between professionals, people using care services, their families, and the communities to which they belong, implying a long-term relationship between people, providers, and health systems where information, decision making, and service delivery become shared. This presentation discusses the importance of an effective and balanced radiation risk-benefit dialogue in pediatric healthcare in the context of people-centered care, to enable informed decision making and achieve the greatest possible benefit at the lowest possible risk.

4:30 pm **Q&A**

4:45 pm **Break**

Forty-Second Lauriston S. Taylor Lecture on Radiation Protection and Measurements

5:00 pm **Introduction of the Lecturer**
R. Julian Preston

Radiation Dosimetry Research for Medicine and Protection: A European Journey
Hans-Georg Menzel

The assessment of doses related to ionizing radiation exposures is an essential part of all applications of ionizing radiation including radiation medicine, radiation protection, radiation biology, radiation epidemiology, and also industrial uses of radiation. Absorbed dose is generally considered to be the fundamental quantity of radiation dosimetry. It is a metrologically sound quantity for which even primary standards exist for some materials and is used routinely in practice.

However, there is no unique correlation between absorbed dose and the radiation induced biological effect considered. There are also different objectives of radiation dosimetry for different applications. In radiation protection, quantities are required to set meaningful exposure limits and to implement the principle of optimization. In radiation therapy the dependence of clinical outcomes on temporal aspects of the irradiations must be accounted for. In radiation diagnostics quantities are needed to enable and monitor optimization of radiation dose and image quality. In radiation protection and in therapy with high linear-energy transfer (LET) radiations appropriate methods and parameters are needed to account for differences in radiation quality. These limitations of the quantity absorbed dose have led to the use of a multiplicity of dose quantities and dose modification factors.

Radiation dosimetry continues, therefore, to be a field of active research regarding fundamental and conceptual aspects taking account of advances in technologies, of novel methods in radiation therapy and diagnostic radiology, and of progress in computational dosimetry. Dosimetry of high-energy radiations such as cosmic radiation encountered at flight altitudes and during space missions as well as at high-energy accelerators has become an important issue.

In Europe, collaboration and coordination of radiation research in general, and dosimetry research in particular, are playing an important role. Dedicated research programs of the European Commission have been and still are very valuable and include collaborations with institutes in Eastern Europe and non-European countries.

In the presentation several current and recent research topics in radiation dosimetry will be addressed based on research carried out within European research programs and at European research centers including the European Organization for Nuclear Research (CERN), in European particle therapy projects, and at national metrological institutes. One focus will be the quantification of radiation quality in radiation protection and in high-LET radiation therapy with emphasis on measurements with low-pressure proportional counters. Another focus will be dosimetry of high-energy radiations with respect to measurements of cosmic radiation and at CERN's high-energy accelerators. Finally, the presentation will deliberate the dose quantities currently used in radiation protection.

6:00 pm **Reception in Honor of the Lecturer**
Sponsored by Landauer, Inc.

LANDAUER®

Tuesday, March 6

8:15 am **NCRP Annual Business Meeting**

9:30 am **Break**

Second Thomas S. Tenforde Topical Lecture

9:45 am

Do the Epidemiologic Data Support Use of the Linear Nonthreshold Model for Radiation Protection?
Roy E. Shore

Low, potentially significant, exposures to low linear-energy transfer (LET) radiation among medical and industrial workers and medical patients have become very common. Historically, we have used the linear nonthreshold (LNT) model for estimating low dose risks and applying standards to protect workers and the public from undue health hazards of radiation.

Is the LNT model still an appropriately prudent basis for radiation protection for low-LET radiation? NCRP Scientific Committee (SC) 1-25 was given the charge to evaluate recent epidemiologic data relevant to the LNT model, primarily covering the past 10 to 15 y which represents the time since the epidemiologic data used by the National Academies' Health Risks from Exposure to Low Levels of Ionizing Radiation (BEIR VII) and the United Nations Scientific Committee on the Effects of Atomic Radiation 2006 reports were compiled. A distinguishing feature of this commentary is that it concentrates on epidemiologic data from low doses or low dose rates (LD/LDR). However, the Life Span Study (LSS) of Japanese atomic-bomb survivors is also reviewed, primarily to characterize the risk in the relatively low-dose range when it was delivered as a brief, one-time exposure rather than in the protracted or highly fractionated fashion characteristic of the LD/LDR studies.

Support for LNT does not necessarily imply that the risk estimates from LD/LDR data be identical to those based on single brief doses in the high-dose range. Rather, there may also be a low dose or low dose-rate effectiveness factor (DDREF) such that the slope of the dose response is reduced, but positive, for low or protracted exposures. A particular concern in evaluating low-dose epidemiologic studies is that the statistical power of a study and the statistical precision of its risk estimate are much less for a low-dose study than a high-dose study. It is therefore challenging to evaluate the implications of studies with low doses or low dose rates.

SC 1-25 evaluated 29 independent studies or groups of studies that reported quantitative results, nearly all of which were based on dose-response analyses of LD/LDR data. The focus was on the endpoint of all solid cancer (or all cancer except leukemia), though we also reported the leukemia results of those studies. Secondarily, the Committee provided brief reviews of whether the LNT model was applicable to *in utero* and childhood exposures, heritable genetic effects, and circulatory disease risk. SC 1-25 critiqued and rated each LD/LDR study of solid cancer on the quality of its dosimetry, epidemiology and statistical analysis and the potential for data biases, which were all part of the Committee's determination of the strength of support the study provided for the LNT model. The best quality, large studies tended to provide the strongest support for the LNT model, and over 75 % of the studies were rated as providing at least some support for the LNT model.

Analyses of whether there was preferential support for other dose-response models was noted whenever relevant results were available. The LSS cohort showed mixed support for a linear-quadratic (LQ) model, but none of the 10 LD/LDR studies with LQ analyses showed statistically significant support for that model. All five studies that evaluated a threshold dose-response model yielded threshold estimates compatible with zero dose (*i.e.*, no dose threshold).

SC 1-25 concluded that there was sufficient epidemiologic evidence consistent with the LNT model to continue to recommend it as a practical and prudent guide for radiation protection purposes. Ultimately, however, it will be necessary to base judgments on the complementary epidemiologic and animal LD/LDR data and to understand the causal and protective mechanisms for radiogenic cancer.

Fostering Innovations

Kimberly E. Applegate & Donald L. Miller, *Session Co-Chairs*

10:15 am

Medical Physics 3.0 to Ensure Quality and Safety in Radiation Medicine

Ehsan Samei
Duke University / American Association of Physicists in Medicine

Radiation protection in medicine is only a component of the broader calling of healthcare professionals: fostering human health. As such, radiation risk needs to be put into context of the broader mandate of improved outcome in healthcare. Medical physicists play a significant role to contribute to this mandate. Facing the new realities of value-based, personalized, and evidence-based practice, Medical Physics 3.0 defines a standard to engage proactively and meaningfully in patient care. This exhibits itself in physicists engaged to ensure precise and optimized use of radiation. Optimization takes place knowing the defining attributes of the technology in use, the specifics of the patient, and the goals of the intervention. Safety as well as the quality of the procedure is ascertained quantitatively and optimized prospectively, ensuring that the proper balance between quality and safety offers the maximum potential benefit to the patient. The results of the procedures across the healthcare operation are then retrospectively analyzed to ensure that each procedure, in actuality, has delivered the targeted quality and safety objectives. Characterizing quality and safety in quantitative terms, objectively optimizing them in the practice of the personalized care, and analyzing the results from clinical operations are unique expertise of precision and innovation that physicists bring to the development and practice of medicine.

10:35 am

Advancing Safety: Role of Equipment Design and Configuration Change

Keith J. Strauss
Cincinnati Children's Hospital Medical Center

Diagnostic x-ray exams irradiate the patient to produce an x-ray pattern in space, which is captured and processed into a visible image, followed by clinical interpretation. Diagnostic quality images at a well-managed radiation dose are required. Improvements to image receptors and image processing algorithms have resulted in improved images at reduced dose levels. However, careful management of x-ray production *via* design or configuration changes of the imaging device also affect patient dose. This initial dose management step is the focus of this discussion.

Imaging equipment vendors, in general, have produced quality images of adults at reasonably managed patient doses. This achievement required teamwork between leading adult hospital staff members and representatives of the imaging equipment vendor within the adult hospital. Most manufacturers have had less opportunity to develop similar optimized configurations for pediatric imaging, the imaging of patients ranging from 2 to 200 kg between 0 to 21 y of age.

Challenges: The wider dynamic range of patient thicknesses in the pediatric size range compared to the adult range of 45 to 200 kg challenges automatic control features. In recent years *reduction* of patient dose as opposed to proper *management* has been stressed. The principal objectives of end-users and vendors are patient care and the "bottom line." This too often hampers if not prevents a productive working relationship between the vendor and the end-user. Too many end-users rely too heavily on their equipment vendor to solve imaging/dose concerns. The vendors have an important role to play in this challenge, but should not be the sole solution.

Qualified medical physicists (QMP) need an understanding of the design of the imaging device, an understanding that many vendors do not support out of proprietary concerns. The performance of the equipment should be judged based on data acquired with better tools.

Solutions: Multiple equipment configurations are needed — each designed to excel at a reduced size range of patients. Dose reductions that significantly impact image quality must be rejected. Radiologists and their QMP should develop target patient doses (size based) for their unique imaging equipment and preferred level of quantum mottle. Once target doses are established as a function of patient size, vendor application specialists, and design engineers, should leverage the equipment's strengths and weaknesses to best achieve desired results.

The QMP should function as an interpreter between the end-user and the vendor's design engineers. Are the radiologists' and technologists' expectations of the vendor reasonable and *vice versa*? While better tools are being developed, vendors may hesitate to make them available, or charge excessive dollars for these new features to further slow their adoption.

Conclusion: The challenges and solutions require the radiologist, technologist, QMP, and vendor representatives to work as a team to manage patient dose and maintain image quality. The installed imaging device will only be as successful as the working relationship between the parties. These challenges and conflicts must continually be overcome to provide the best patient care.

10:55 am

How Innovations in Computer Technologies Have Impacted Radiation Dosimetry Through Anatomically Realistic Phantoms and Fast Monte-Carlo Simulations

X. George Xu
Rensselaer Polytechnic Institute

Radiation dosimetry principles have not changed in the past 60 y during which computer technologies have advanced exponentially. The research field of anatomical modeling for the purpose of radiation dose calculations has experienced an explosion in activity in the past two decades. Such an exciting advancement is due to the feasibility to perform Monte-Carlo radiation-transport simulations on increasingly fast and cheap personal computers. Recently, the advent of a new type of high-performance computing hardware — the so-called co-processors such as the graphics processing unit (GPU) and many-integrated core (MIC) technologies — has made it possible to carry out time-consuming Monte-Carlo calculations in near real-time speeds. In this presentation, I will first introduce three generations of computational human models (the stylized medical internal radiation dose-type phantoms, the voxelized tomographic phantoms, and the boundary representation deformable phantoms). Using examples, I will then discuss how these unprecedented technologies have improved radiation protection, imaging, and radiotherapy. I will report on the latest development of ARCHER the world's only Monte-Carlo code that can run on central processing unit, GPU, and MIC platforms. I will end the presentation by commenting on the feasibility of adopting artificial intelligence to improve the workflow in radiation protection monitoring and treatment planning.

11:15 am **Q&A**

11:30 am **Break**

Conclusions and Path Forward

Lawrence T. Dauer & Donald P. Frush, *Session Co-Chairs*

11:45 am

Radiation Protection Responsibility in Medicine: A Wrap Up

Donald P. Frush
Duke University Medical Center

12:00 pm

NCRP Vision for the Future and Program Area Committee Activities
John D. Boice, Jr.
President, NCRP

12:30 pm

Adjourn

Program Committee

Lawrence T. Dauer, *Co-Chair*
Memorial Sloan Kettering Cancer Center

Donald P. Frush, *Co-Chair*
Duke Medical Radiation Center

Linda A. Kroger
University of California Davis School of Medicine

Fred A. Mettler, Jr.
University of New Mexico School of Medicine

Donald L. Miller
U.S. Food & Drug Administration

Julie E.K. Timins
New Jersey Commission on Radiation Protection

Pat B. Zanzonico
Memorial Sloan Kettering Cancer Center

Registration

Monday, March 5, 2018	7:00 am – 5:00 pm
Tuesday, March 6, 2018	7:00 am – 11:00 am

Register online: http://registration.ncrponline.org

2019 Annual Meeting

NCRP at Ninety: Our Best Answers to Frequently Asked Questions

Fred A. Mettler, Jr., Chair;
Jerrold T. Bushberg & Richard J. Vetter, *Co-Chairs*

April 1–2, 2019
Bethesda, Maryland

Lauriston S. Taylor Lecture

Dr. Hans-Georg Menzel has been selected to give the 42nd Lauriston S. Taylor Lecture at the 2018 Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP). The lecture, entitled “Radiation Dosimetry Research for Medicine and Protection: A European Journey,” will be the featured presentation at the 54th Annual Meeting to be held March 5-6, 2018. The Lecture will be given in the Crystal Ballroom of the Hyatt Regency Bethesda, One Bethesda Metro Center, 7400 Wisconsin Avenue, Bethesda, Maryland at 5:00 p.m. on March 5, 2018. The lecture series honors the late Dr. Lauriston S. Taylor, NCRP Founding President (1929 to 1977) and President Emeritus (1977 to 2004).

Dr. Menzel's scientific career in radiation and medical physics started in 1970 at the Joint Research Center of the European Commission in Ispra, Italy. He continued his research work in 1973 at the German Cancer Research Centre in Heidelberg and at the Medical Faculty of University of Saarland, Germany. Following 10 y as senior scientific officer for radiation protection research at the European Commission in Brussels, Belgium he joined in 1999 the European Organization for Nuclear Research (known as CERN) in Geneva, Switzerland as Leader of the Radiation Protection Group. His management and scientific responsibilities included operational radiation protection of CERN's accelerators and experimental areas, radiation safety for the construction of the Large Hadron Collider and other new research facilities, and for safely handling radioactive waste. In 2009 he retired from CERN as Honorary Staff Member.

His academic career included teaching at the University of Saarland and being invited professor at the Nuclear Physics Department, as well as at the Medical Faculty of the Université Catholique Louvain (Belgium). By invitation, he has been a member of examination boards for PhD students of physics at universities in Germany, Belgium, The Netherlands, France, and Sweden.

Dr. Menzel's research activities include experimental and theoretical multidisciplinary research and applications in the areas of nuclear physics, solid-state physics, medical physics, radiation dosimetry, radiobiology, radiation therapy, and radiation protection. His experience comprises scientific and administrative management for research projects funded by German and European agencies. This involved guiding and coordinating the work of scientists as well as PhD students in several European research institutes. His work has led to more than 120 publications, including review papers in refereed scientific journals, conference proceedings, and monographs. Numerous lectures were presented at international scientific conferences worldwide, several of them by invitation of conference organizers.

Dr. Menzel has been Chairman of the International Commission on Radiation Measurements and Units (ICRU) since 2009 and a Commissioner since 1993. His ICRU activities include membership of the Standing Committee on Fundamental Quantities and Units for Ionizing Radiation. He served as a Member of the Main Commission of the International Commission on Radiological Protection (ICRP) and as Chairman of ICRP Committee 2 as well as on several ICRP task groups. Dr. Menzel is an Observer to the United Nations Scientific Committee on the Effects of Atomic Radiation and Chairman of the International Atomic Energy Agency's Scientific Committee on Secondary Standard Dosimetry Laboratories. He was also a Member of the U.S. National Academy of Sciences' Committee for the Evaluation of the Space Radiation Cancer Risk Model of the National Aeronautics and Space Administration.

Dr. Menzel was the 2000 G. William Morgan Lecturer of the Health Physics Society and the H.H. Rossi Lecturer at the MICROS 2017, 17th International Symposium on Microdosimetry.

Annual Warren K. Sinclair Keynote Address

Marvin Rosenstein has been selected to give the 15th Warren K. Sinclair Keynote Address at the 2018 Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP). The Address, entitled "Jus•ti•fied and Com•men•su•rate" will be a featured presentation at the 54th NCRP Annual Meeting to be held March 5-6, 2018. The Address will be given at 8:30 a.m. on March 5, 2018 in the Crystal Ballroom, Hyatt Regency Bethesda, One Bethesda Metro Center, 7400 Wisconsin Avenue. The keynote speaker series honors Dr. Warren K. Sinclair, NCRP's second President (1977 to 1991).

Dr. Rosenstein is a consultant, currently concentrating on the preparation of scientific reports produced by NCRP in all subject areas of the NCRP program. He has been the Staff Consultant on 20 NCRP reports or commentaries starting in 1999 and continuing through 2017.

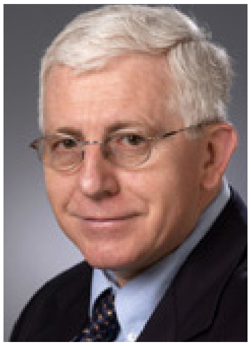
From 1982 to 1995, he was Director, Office of Health Physics at the Center for Devices and Radiological Health, Food and Drug Administration. He also served in a number of scientific and management positions related to radiation protection during his 33 y career as a Commissioned Officer in the U.S. Public Health Service, from 1962 to 1995.

He received a BS in Chemical Engineering (University of Maryland, 1961), an MS in Environmental Engineering (Rensselaer Polytechnic Institute, 1966) and a PhD in Nuclear Engineering (University of Maryland, 1971). His technical work has concentrated on radiation dosimetry, particularly with regard to x rays used for medical diagnosis, epidemiological studies of exposed populations, and public radiation emergencies.

He is a Distinguished Emeritus Member of the NCRP [after serving as a Council member for 18 y (1988 to 2006)], and an Emeritus member of Committee 3 (Protection in Medicine) of the International Commission on Radiological Protection (ICRP) [after serving on Committee 3 for 28 y (1985 to 2013)].

Of particular note, he was a member of the International Commission on Radiation Units and Measurements committee that produced Report 74, Patient Dosimetry for X Rays Used in Medical Imaging (2005); Chair of the Task Group that produced ICRP Publication 105, Radiological Protection in Medicine (2007); and a member of the ICRP Working Party that produced Publication 135, Diagnostic Reference Levels in Medical Imaging (2017).

Thomas S. Tenforde Topical Lecture



Roy E. Shore has been selected to give the Second Thomas S. Tenforde Topical Lecture at the 2018 Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP). The Address, entitled "Do the Epidemiologic Data Support the Use of the Linear-Nonthreshold Model for Radiation Protection?" will be a featured presentation at the 54th NCRP Annual Meeting to be held March 5- 6, 2018. The Lecture will be given at 9:45 a.m. on March 6, 2018 in the Crystal Ballroom, Hyatt Regency Bethesda, One Bethesda Metro Center, 7400 Wisconsin Avenue. The keynote speaker series honors Dr. Thomas S. Tenforde, NCRP's fourth President (2002 to 2012).

Dr. Shore began his career at New York University (NYU) School of Medicine in 1969 and advanced to the position of Professor and Director of the Cancer Epidemiology and Prevention Program at NYU's Cancer Institute until 2005 when he accepted the position of Vice Chairman and Chief of Research at the Radiation Effects Research Foundation in Hiroshima-Nagasaki until his retirement in 2015.

Dr. Shore was elected as an NCRP Distinguished Emeritus Member in 2008 after serving as a Council Member from 1983 to 2001 and 2002 to 2008 and on the Board of Directors from 1995 to 2001. He is Chair of Scientific Committee (SC) 1-25 on Recent Epidemiologic Studies and Implications for the Linear-Nonthreshold Model, and a member of Program Area Committee 1 on Basic Criteria, Epidemiology, Radiobiology, and Risk and SC 1-26 on Approaches for Integrating Radiation Biology and Epidemiology for Enhancing Low Dose Risk Assessment. He currently serves as Staff Consultant for the Million Person Study and has past experience on several scientific committees and participated in several NCRP annual meetings either as a program committee member or speaker.

He has served on numerous governmental and scholarly committees, including as a long-time member of the International Commission on Radiological Protection and has served on various committees or task groups for the United Nations Scientific Committee on the Effects of Atomic Radiation, the World Health Organization, the National Academy of Sciences, the National Cancer Institute, and the U.S. Environmental Protection Agency, among others. His interests include the effects of radiation on both cancer and noncancer disease rates, and understanding the epidemiological and biological modification of radiation effects by various environmental, genetic and age factors. He is particularly interested in epidemiological evidence regarding health effects at low doses and low dose rates and is an author of about 150 radiation-related publications.

Dr. Shore earned a BA from Houghton College in 1962, a PhD from Syracuse University in 1967, and a Doctor of Public Health from Columbia University in 1982. He is a Fellow of the American College of Epidemiology and is a member of the Society for Epidemiologic Research, American Association of Cancer Research, and the Radiation Research Society.

Biographies

Kimberly E. Applegate, *Session Co-Chair/Speaker*, is a tenured professor of radiology and pediatrics at the University of Kentucky, and the department liaison for quality to the Kentucky Children's Hospital. She is a member of NCRP and serves on Program Area Committee 4 on Radiation Protection in Medicine.

Dr. Applegate is an internationally recognized leader in quality and safety. She has received the Marie Curie Award from the American Association for Women in Radiology for leadership and mentorship in radiology, the Gold Medal from the Association for University Radiologists and the Indiana State Chapter of the American College of Radiology. Dr. Applegate is passionate about improving patient care, especially children; she has been a steering committee member of the Image Gently® Alliance since its inception. The mission of the alliance is, through advocacy, to improve the imaging care of children worldwide. She is a member of the Main Commission of the International Commission on Radiological Protection as chair of Committee 3 on medicine.

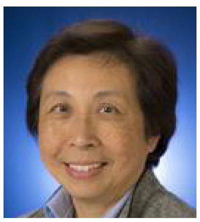
John D. Boice, Jr., *President/Speaker*, is the President of the National Council on Radiation Protection and Measurements (NCRP), Bethesda, Maryland, and Professor of Medicine at Vanderbilt University School of Medicine, Nashville, Tennessee. He is an international authority on radiation effects and served on the Main Commission of the International Commission on Radiological Protection for 20 y and as a U.S. advisor to the United Nations Scientific Committee on the Effects of Atomic Radiation for 25 y. During 27 y of service in the U.S. Public Health Service, Dr. Boice developed and became the first chief of the Radiation Epidemiology Branch at the National Cancer Institute.

Dr. Boice has established programs of research in all major areas of radiation epidemiology, with major projects dealing with populations exposed to medical, occupational, military and environmental radiation. These research efforts have aimed at clarifying cancer and other health risks associated with exposure to ionizing radiation, especially at low-dose levels. Dr. Boice's seminal discoveries and over 500 publications have been used to formulate public-health measures to reduce population exposure to radiation and prevent radiation-associated diseases.

He has delivered the Lauriston S. Taylor Lecture at the NCRP and the Fessinger-Springer Lecture at the University of Texas at El Paso. In 2008, Dr. Boice received the Harvard School of Public Health Alumni Award of Merit. He has also received the E.O. Lawrence Award from the Department of Energy — an honor bestowed on Richard Feynman and Murray Gell-Mann among others — and the Gorgas Medal from the Association of Military Surgeons of the United States. In 1999 he received the outstanding alumnus award from the University of Texas at El Paso (formerly Texas Western College). Dr. Boice directs the Million U.S. Radiation Workers and Veterans Study to examine the lifetime risk of cancer following relatively low-dose exposures received gradually over time.

Jerrold T. Bushberg, *Senior Vice President/Speaker*, is the Chairman of the Board and Senior Vice President of NCRP and Associate Chair and Clinical Professor of Radiology and Clinical Professor of Radiation Oncology at the University of California (UC) Davis School of Medicine. He is an expert on the biological effects, safety and interactions of ionizing and nonionizing radiation and holds multiple radiation detection technology patents. With over 35 y of experience he has served as a subject matter expert and an advisor to government agencies and institutions throughout the nation and around the world including the U.S. Department of Homeland Security, the World Health Organization, and the International Atomic Energy Agency in the areas of radiation protection, risk communication, medical physics, and radiological emergency medical management. Dr. Bushberg is an elected fellow of the American Association of Physicists in Medicine and the Health Physics Society. He is certified by several national professional boards with specific subspecialty certification in radiation protection and medical physics and currently serves as a Director and Vice-Chair of the American Board of Medical Physics. In 2014, Dr. Bushberg was awarded the Warren K. Sinclair Medal for Excellence in Radiation Science by NCRP in 2014. Prior to coming to the UC Davis Health System as technical director of Nuclear Medicine, Dr. Bushberg was on the faculty of Yale

University School of Medicine Department of Radiology where his research was focused on radiopharmaceutical development. Dr. Bushberg has responsibility for medical postgraduate education in medical physics, radiation (ionizing and nonionizing) biology and protection. The third edition of the textbook *The Essential Physics of Medical Imaging*, authored by Bushberg, Seibert, Leidholdt, and Boone, is used extensively by radiology residency programs throughout the United States.



Polly Y. Chang, *Session Co-Chair*, is the Senior Director of the Molecular and Genetic Toxicology Program in SRI International's Biosciences Division.

Dr. Chang received her BA in mammalian physiology, MA in bioradiology, and PhD in radiation biology/biophysics from the University of California, Berkeley. She is serving as the leader on a number of National Institute of Health, National Aeronautics and Space Administration, Biomedical Advanced Research and Development Authority (BARDA), and commercially sponsored projects, conducting both basic mechanistic and efficacy studies using *in vitro* and *in vivo* model systems. During her tenure at SRI, Dr. Chang has led multiple nonclinical product development programs, including vaccines, biologics, metal decorporation agents, and small molecules that have resulted in over 10 approved IND applications. She served as a co-investigator on a BARDA-funded biodosimetry project to develop a point-of-care biodosimeter for early detection of radiation exposure. The instrument is currently in the validation phase and will be moving through the U.S. Food and Drug Administration's regulatory approval. She has served on NCRP Scientific Committee (SC) 1-20 on the biological effectiveness of low energy radiation and is currently serving on SC 1-24 on space radiation effects on the central nervous system.

Mythreyi Chatfield, *Speaker*, is the Executive Vice President of Quality and Safety at the American College of Radiology (ACR) where she oversees the accreditation programs, registries, Appropriateness Criteria, and other quality activities. Prior to May 2010, she was Director of Research at ACR, where she conducted research on socioeconomic topics of relevance to radiology, including monitoring trends in imaging utilization and costs, small-area variations in healthcare use, and racial and ethnic disparities in access to care.

Lawrence T. Dauer, *Program Committee Co-Chair/Session Co-Chair/Speaker*, is Corporate Radiation Safety Officer, Associate Attending Physicist, and Associate Clinical Member in the Departments of Medical Physics and Radiology at Memorial Sloan Kettering Cancer Center (MSKCC) in New York City. He earned an MS in Health Physics and a PhD in Adult Education. He is certified in comprehensive health physics by the American Board of Health Physics and is past chair of the Radiation Safety Committee of the American Association of Physicists in Medicine (AAPM), past President of the Greater New York Chapter of the Health Physics Society (HPS), Executive Council Member of the Medical Physics Section of HPS, a Member of the Joint Safety Committee of the Society for Interventional Radiology and the American College of Radiology, past council member of the Radiological and Medical Physics chapter of AAPM, and a member of editorial and review boards of several scientific journals. He received the Elda E. Anderson Award from HPS in 2005, and was named an HPS Fellow in 2017. He is a Council member and serves on the Board of Directors of NCRP. He also served as a member of the International Commission on Radiological Protection Committee 3 on protection in medicine, a member of the science council for the International Organization for Medical Physics, and was on the program committee for the International Atomic Energy Agency's International Conference on Radiation Protection in Medicine – Setting the Scene for the Next Decade. He serves on the Radiation Advisory Committee of the U.S. Environmental Protection Agency's Science Advisory Board. He has several publications in the topical areas of radiation protection and risks in the fields of detection, radiology, interventional radiology, x-ray imaging, nuclear medicine, and radiation oncology, as well as surgery and medicine.

Biographies

Frederic H. Fahey, *Speaker*, has been the Director of Nuclear Medicine/Positron Emission Computed Tomography (PET) Physics at Boston Children's Hospital since 2003 and is a Professor of Radiology at Harvard Medical School. He received his DSc from the Harvard School of Public Health in Medical Radiological Physics in 1986. Dr. Fahey is certified in nuclear medical physics by the American Board of Radiology. Prior to coming to Boston Children's Hospital, he had worked at Georgetown School of Medicine from 1984 to 1991 and Wake Forest School of Medicine from 1991 to 2003. He served as president of the Society of Nuclear Medicine and Molecular Imaging (SNMMI) in 2012 to 2013. He is currently the SNMMI liaison to the U.S. Department of Energy Nuclear Sciences Advisory Committee. He is a consultant to the International Atomic Energy Agency and sits on the Nuclear Medicine Technologist Certification Board. He is a fellow of the Society of Nuclear Medicine and Molecular Imaging, the American College of Radiology, and the American Association of Physicists in Medicine. His research interests include PET and single-photon emission computed tomography instrumentation, image processing, reconstruction of tomographic data, and radiation dosimetry, particularly in the realm of pediatric nuclear medicine. He is actively involved in the Image Gently® and Image Wisely® campaigns as they pertain to nuclear medicine.

Donald P. Frush, *Program Committee Co-Chair/Session Co-Chair*, is the John Strohbehn Professor of Radiology, Professor of Pediatrics, Vice Chair for Safety and Quality, faculty member of the Medical Physics Graduate Program, and Medical Director of the Duke Medical Radiation Center. Dr. Frush received a BS from The University of California Davis, an MD from Duke University, was a pediatric Resident at University of California San Francisco from 1985 to 1987, a radiology resident at Duke, and finished a pediatric radiology fellowship at Children's Hospital Medical Center in Cincinnati in 1992.

Dr. Frush's research interests are predominantly focused on pediatric body computed tomography (CT), including technology assessment, techniques for pediatric multidetector computed tomography examinations, assessment of image quality, and CT radiation dosimetry and dose reduction. International affiliations include the World Health Organization and the International Atomic Energy Agency. Dr. Frush is currently a board member of the Society for Pediatric Radiology as well as NCRP, Chair of the Image Gently® Alliance, Trustee of the American Board of Radiology, and a Fellow of Society of Computed Body Tomography and Magnetic Resonance.

Helen A. Grogan, *Session Co-Chair*, is President of Cascade Scientific, Inc., an environmental consulting firm. Dr. Grogan received her PhD from Imperial College of Science and Technology at the University of London in 1984 and has more than 25 y of experience in radioecology, environmental dose reconstruction, and the assessment of radioactive and nonradioactive hazardous waste. She first worked at the Paul Scherrer Institute in Switzerland on the performance assessment of radioactive waste disposal for the Swiss National Cooperative for the Disposal of Radioactive Waste (Nagra). Dr. Grogan was actively involved in the early international cooperative efforts to test models designed to quantify the transfer and accumulation of radionuclides and other trace substances in the environment.

Validation of computer models developed to predict the fate and transport of radionuclides in the environment remains a key interest of hers. In 1989 Dr. Grogan returned to the United Kingdom as a senior consultant to Intera Information Technologies before moving to the United States a few years later, where she has worked closely with the Risk Assessment Corporation managing the technical aspects of a wide variety of projects that tend to focus on public health risk from environmental exposure to chemicals and radionuclides. Dr. Grogan has served on committees for the National Academy of Sciences, the International Atomic Energy Agency, the U.S. Environment Protection Agency, and NCRP. She co-edited the text book *Radiological Risk Assessment and Environmental Analysis* published by Oxford University Press in July 2008, and authored the chapter on Model Validation.

Randall N. Hyer, *Session Co-Chair*, Senior Fellow and Assistant Director for Environmental, Health and Safety, Center for Risk Communication.

Dr. Hyer graduated with distinction from the U.S. Naval Academy, and served 12 y on active duty in the U.S. Navy. After earning his medical degree from Duke University, Dr. Hyer served as the 40th Winter-Over Medical Officer and Assistant Officer-in-Charge with Operation DEEP FREEZE at McMurdo and South Pole Stations in Antarctica. Dr. Hyer earned his PhD from Oxford, studying the molecular genetics of juvenile diabetes and helped determine the role of the insulin gene in disease susceptibility.

In 1994, the National Institutes of Health awarded Dr. Hyer the "NIH Outstanding Research Award for Clinical Trainees." Trained in public health at Walter Reed Hospital and Harvard University, Commander Hyer supported four major military operations in the European, African, and southwest Asian theaters to include service as Chief Public Health Advisor for the Kosovo operations and Deputy Surgeon for the Mozambique flood-relief operations. Dr. Hyer then spent 4 y at the World Health Organization (WHO) in Geneva as the first WHO Civil Military Liaison Officer and served as part of the WHO's outbreak response team to deadly outbreaks like anthrax, SARS, and avian influenza as well as having organized missions during the 2005 Tsunami response. His experiences with the media in outbreaks and emergencies led him to co-author the popular WHO handbook, *Effective Media Communication During Public Health Emergencies*.

Appointed a U.S. Congressional Fellow for Senator Pete V. Domenici (R-New Mexico), he helped introduce legislation to safeguard genetic privacy that eventually became the Genetic Information Non-discrimination Act (GINA) of 2008. In 2005, Dr. Hyer joined Merck Vaccine Division in Global Medical Affairs and Policy. His focus has been the human papilloma virus (HPV) vaccine. In 2009, he was transferred to MSD in Tokyo, Japan.

Linda A. Kroger, *Program Committee/Session Co-Chair*, is Assistant Clinical Professor of Radiology at the University of California (UC) Davis School of Medicine and has served as the Radiation Safety Officer for the UC Davis Health System for the past 10 y. Ms. Kroger received her undergraduate degree and her Masters Degree from Rutgers University. She has been with UC Davis for 25 y. Prior to her arrival at UC Davis, Ms. Kroger worked for private industry in biopharmacology research and drug development. She transitioned to cancer research when she joined UC Davis in 1988. From 1988 through 2000, her research focused on the development of new radiopharmaceuticals for both diagnostic imaging and treatment of non-Hodgkin's lymphoma and breast cancer. Since assuming her role as Radiation Safety Officer in 2003, she has focused on regulatory compliance, quality assurance issues as well as education of medical students, residents and fellows with the overall goal of improving workplace radiation safety. Ms. Kroger oversees the nonclinical aspects of nuclear medicine training for the radiology residency program at UC Davis. In addition, she has taken an interest in radiologic emergency preparedness. Ms. Kroger has authored or co-author more than 50 peer-reviewed journal articles and has presented at numerous scientific conferences. She has served in a number of roles in both the local chapter as well as the national Health Physics Society and been an active participant on NCRP committees since 2005.

Alan G. Lurie, *Speaker*, is Professor and Chair of the Division of Oral and Maxillofacial Diagnostic Sciences and Chair of the Section of Oral and Maxillofacial Radiology (OMFR), Department of Oral Health and Diagnostic Sciences at the University of Connecticut (UCONN) School of Dental Medicine. He has secondary appointments as Professor of Diagnostic Imaging and Therapeutics in the UCONN School of Medicine and Professor in the Center for Latin American and Caribbean Studies in the UCONN College of Liberal Arts and Sciences. He completed a DDS at the University of California Las Angeles in 1970, and a PhD in Radiation Biology and Biophysics at the University of Rochester in 1974. He has been a full-time faculty member in OMFR since 1973, during which time he has done R01 research on radiation carcinogenesis, administered predoctoral and graduate educational programs, been Program Director for the OMFR Residency Program, conducted clinical research, and performed imaging care on patients in both dental and medical radiology settings. Dr. Lurie is a long-time active member, Past President, and Fellow of the American Academy of Oral and Maxillofacial Radiology. He is a Past Director and President of the American Board of Oral and Maxillofacial Radiology, and founding and Immediate Past Chair of the Image Gently® in Dentistry Group, receiving the 2016 Butterfly Award from Image Gently®. Dr. Lurie has over 100 publications in the refereed literature, and numerous presentations to local, state, national and international organizations. He was a member of NCRP Scientific Committee (SC) 91-2, "Radiation Safety in Dentistry", and Co-Chaired SC 4-5 that prepared NCRP Report No. 177 on radiation safety in dentistry and OMF radiology. He is now the dental and OMFR representative on NCRP.

Mahadevappa Mahesh, *Session Co-Chair*, is Professor of Radiology and Medicine at the Johns Hopkins University School of Medicine, Baltimore, Maryland. He is also the Chief Physicist at the Johns Hopkins Hospital in Baltimore and Professor of Environmental Health and Engineering at the Johns Hopkins Bloomberg School of Public Health.

Dr. Mahesh obtained his PhD in Medical Physics from the Medical College of Wisconsin, Milwaukee. Dr. Mahesh is board certified from the American Board of Radiology in diagnostic radiological physics and is a member of the Radiation Control Advisory Board for the State of Maryland. His research interests are in medical imaging, particularly in areas of multiple-row detector computed tomography (MDCT), interventional fluoroscopy, and digital mammography. As Chief Physicist, he oversees the quality assurance program for diagnostic radiology that includes maintaining compliance with regard to state and federal regulations and ensuring safe use of radiation to patients. He often provides counsels to patients concerned over their radiation exposure from diagnostic x-ray examinations.

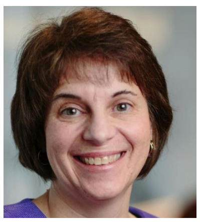
Dr. Mahesh has been the editor of the physics columns ("Technology Talk" and "Medical Physics Consult") for the *Journal of American College of Radiology* (JACR) since 2007. He is also the Associate Editor of JACR, Deputy Editor for *Academic Radiology* and Editorial Board Member for *RadioGraphics* and *Radiology* journals. He is Treasurer for the American Association of Physicists in Medicine (AAPM) and board member of the Society of Cardiovascular Computed Tomography (SCCT). He is a fellow of the AAPM (2007), ACR (2009), American College of Medical Physics (2011), and SCCT (2011).

Dr. Mahesh has been invited to be the United Nations-International Atomic Energy Agency (UN-IAEA) expert to participate in IAEA activities. Dr. Mahesh is the author of the textbook titled *MDCT Physics: The Basics – Technology, Image Quality and Radiation Dose*. He publishes and lectures extensively here in the United States and internationally in the area of MDCT technology, radiation doses in medical imaging, and other medical physics areas.

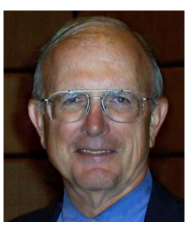
Dr. Mahesh is on the NCRP Council and was a member of NCRP Scientific Committee (SC) 6-2 that published NCRP Report No. 160, *Ionizing Radiation Exposure of the United States Population*. He is the co-chair of NCRP SC 4-9 on Medical Exposure of the U.S. Population.

Melissa C. Martin, *Speaker*, has been President of Therapy Physics Inc., a consulting medical physics group of certified medical physicists based in Southern California which provides diagnostic medical physics services throughout the Western United States, since 1995. She received her MS in Medical Physics from the University of California Los Angeles and is certified in Radiological Physics by the American Board of Radiology. Ms. Martin has extensive experience providing shielding design reports for radiation therapy vaults for all types of therapy equipment having completed these reports for over 400 vaults throughout the world. She has recently completed a 3 y appointment as the U.S. Representative to the International Organization for Standardization (ISO)/Technical Committee writing the ISO Standard on *Radiation Protection for Medical and Veterinary Use of Linear Accelerators*. She was a hospital-based physicist for over 15 y working in both diagnostic imaging and radiation therapy departments developing her expertise in diagnostic imaging physics, particularly mammography physics. Ms. Martin was one of the American Association of Physicists in Medicine (AAPM) physicists that developed the Mammography Quality Standards Act and

Program. She has been very active in AAPM in both the local Southern California Chapter and the national AAPM serving as a national Board member for 18 y as Chapter Representative, Board Member-at-Large, Treasurer, and lately as the Administrative Council Chair and current President (2017). Ms. Martin has served the AAPM as a liaison to the Conference of Radiation Control Program Directors for over 20 y working to build a strong working relationship between the AAPM and the regulatory community. Ms. Martin is a Fellow of AAPM, the American College of Radiology, and the American College of Medical Physics and has worked with the American Board of Radiology for the past 10 y on both the written and oral exams in diagnostic imaging physics.



Cynthia H. McCollough, *Speaker*, is a Professor of Medical Physics and Biomedical Engineering at the Mayo Clinic in Rochester, Minnesota. As Director of Mayo Clinic's Computed Tomography (CT) Clinical Innovation Center, Dr. McCollough leads a multi-disciplinary team of physicians, scientists, research fellows, and graduate students on projects seeking to detect and quantify disease using CT imaging. She has particular expertise in the use of CT for quantitative assessment of material composition, disease progression or regression, and organ function, as well as methods to quantity and reduce patient dose.
Dr. McCollough is internationally recognized for her contributions to the fields of CT imaging physics and technology, and radiation dosimetry and protection. She has served in many leadership positions in the radiology, medical physics, and radiation protection communities, and testified before Congressional and U.S. Food and Drug Administration (FDA) panels on the topic of dose management in CT. She currently serves on the FDA's Technical Electronic Product Radiation Safety Standards Committee, is a U.S. representative to the International Electrotechnical Commission's CT Standards Committee, and is president-elect of the American Association of Physicists in Medicine. Dr. McCollough is the author of over 300 peer-reviewed publications.

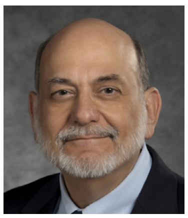


Fred A. Mettler, Jr., *Program Committee*, is Professor Emeritus and Clinical Professor at the Department of Radiology at the University of New Mexico School of Medicine. He was chairman of the department for 18 y from 1994 to 2003. He is currently in the Radiology and Nuclear Medicine Service at the New Mexico Federal Regional Medical Center.

He graduated with a BA in Mathematics from Columbia University and in 1970 he received his MD from Thomas Jefferson University. He performed a rotating internship at the University of Chicago and subsequently completed a Radiology and Nuclear Medicine Residency at Massachusetts General Hospital. He received an MS in Public Health from Harvard University in 1975. He is a fellow of both the American College of Radiology and the American College of Nuclear Physicians. He is board certified in both radiology and nuclear medicine.

Dr. Mettler has authored over 360 scientific publications including 20 textbooks, and holds four patents. The books are on *Medical Management of Radiation Accidents*, *Medical Effects of Ionizing Radiation,* and *Radiology and Nuclear Medicine*. He was a Scientific Vice President of NCRP and remains a member. He has chaired several committees for the Institute of Medicine/National Research Council and is a member of the Nuclear and Radiation Studies Board of the National Academies. He is also an academician of the Russian Academy of Medical Sciences. Dr. Mettler has been listed in *The Best Doctors in America* since 1994 as an expert in both nuclear medicine and radiation injury. He has been a certifying examiner for the American Board of Radiology for 30 y.

He was the U.S. Representative to the United Nations Scientific Committee on the Effects of Atomic Radiation 28 y. He is an Emeritus Commissioner of the International Commission on Radiological Protection (ICRP). He was the Health Effects Team Leader of the International Chernobyl Project and has served as an expert on radiation effects and accidents for the Centers for Disease Control and Prevention, the World Health Organization, the International Atomic Energy Agency, the International Agency on Research on Cancer, and for the Costa Rican, Peruvian, Panamanian, Polish governments. He was a co-author of the NCRP and ICRP reports on radiation protection during radiological terrorism and has been a member of multiple subgroups on radiological terrorism for the U.S. Department of Homeland Security. He is currently a health advisor to the Japanese Cabinet for the Fukushima nuclear disaster.



Donald L. Miller, *Program Committee/Session Co-Chair*, is Chief Medical Officer for Radiological Health at the U.S. Food and Drug Administration's (FDA) Center for Devices and Radiological Health. He earned a BA from Yale University and an MD from New York University, and completed a residency in diagnostic radiology and a fellowship in interventional radiology at New York University Medical Center. He is board certified in Diagnostic Radiology and Vascular and Interventional Radiology. Prior to joining FDA, he practiced interventional radiology at the National Institutes of Health and the National Naval Medical Center in Bethesda, Maryland.

Dr. Miller was elected to NCRP in 2006. He currently serves on the Board of Directors, as Chair of Program Area Committee 4 (Radiation Protection in Medicine), Chair of the Nominating Committee, and as a member of several scientific committees. He is an author of NCRP Reports No. 168 and No. 172 and Statement No. 11. He served as a member of the International Commission on Radiological Protection (ICRP) Committee 3 (Protection in Medicine) from 2010 to 2017. He is an author of ICRP Publications 117 and 120. He was Vice-Chair for the U.S. Environmental Protection Administration's Federal Guidance Report No. 14, is a consultant to the International Atomic Energy Agency, and is a member of the World Health Organization's Core Group of Experts on Radiation Protection of Patients and Staff.

Dr. Miller was Professor of Radiology at the Uniformed Services University in Bethesda, Maryland from 1993 to 2012 and has served as Associate Editor of Radiology and the Journal of Vascular and Interventional Radiology. He is an author of more than 185 papers in peer-reviewed journals and more than 30 book chapters and reports, is a Fellow of the Society of Interventional Radiology (SIR) and the American College of Radiology (ACR) and is an Honorary Member of the American Association of Physicists in Medicine. He chaired SIR's Safety and Health Committee from 1999 to 2011 and the ACR Guidelines Interventional Committee from 2008 to 2012. His research interests have centered on radiation protection in medicine.

Kate Niehaus, *Speaker*, has her BA from Wesleyan University and an MBA from Harvard Business School. Until January 2018 she served as the Chair of the Patient and Family Advisory Council for Quality (PFACQ) at Memorial Sloan Kettering Cancer Center (MSKCC) and currently sits on the Hospital Ethics Committee and the Hospital Quality Assessment Committee. Ms. Niehaus has been a patient advisor for 10 y at MSKCC, worked on quality improvement projects, participated in root-cause analyses, served in a patient peer mentoring program, and has spoken publicly about her experience as a patient and as the Chair of the PFACQ.

She was recently named to the Technical Expert Panel for the project "Quality Measure Development: Supporting Efficiency and Innovation in the Process of Developing CMS Quality Measures" and to the Quality Committee for the Alliance of Dedicated Cancer Centers in the United States. In August 2017 she participated in a roundtable discussion sponsored by NEJM Catalyst on the topic of "Measuring what Matters and Capturing the Patient Voice."

She is also the President of the Board of the Greater New York Chapter of the Cystic Fibrosis Foundation and the President of the Robert and Kate Niehaus Foundation.

Biographies

María del Rosario Pérez, *Speaker*, is a physician who received her MD in 1980 from the School of Medicine of Buenos Aires University, Argentina, where she later specialized on Radiation Oncology. In 1990 she obtained a post-graduate diploma on Radiation Protection and Nuclear Safety delivered by the School of Engineering of the Buenos Aires University and the National Atomic Energy of Argentina in cooperation with the International Atomic Energy Agency (IAEA). She completed her formation in Epidemiology in 1991 at the National Academy of Medicine and since then her professional career has been focused on radiation protection and human health. She was Head of the Radiopathology Laboratory at the Nuclear Regulatory Authority in Argentina where she coordinated research projects on the effects of ionizing radiation on the immune system, consequences of prenatal irradiation on the developing brain, the effects of ionizing radiation on dermal endothelial cells, diagnosis and treatment of radiation injuries, bioindicators of radiation exposure, and radiation epidemiology. Dr. Pérez contributed to radiation protection education and training programs in Latin America, and participated in international expert teams involved in the preparedness and response in radiation emergencies. She has been working at the World Health Organization (WHO) Radiation Programme since 2007. She contributed to the revision of the International Radiation Basic Safety Standards (BSS), as a WHO representative at the Joint BSS Secretariat. She represents WHO at the Inter-Agency Committee on Radiation Safety, the IAEA Radiation Safety Standards Committee, the International Commission on Radiological Protection, and the European Commission Group of Scientific Experts referred to in Article 31 of the Euratom Treaty. Her main responsibility at WHO is the technical coordination of the WHO Global Initiative on Radiation Safety in Health Care Settings.

R. Julian Preston, *Speaker*, retired as the Associate Director for Health for the National Health and Environmental Effects Research Laboratory of the U.S. Environmental Protection Agency (EPA). He also served as Director of the Environmental Carcinogenesis Division at EPA and as senior science adviser at the Chemical Industry Institute of Toxicology. He has been employed at the Biology Division of the Oak Ridge National Laboratory and served as associate director for the Oak Ridge-University of Tennessee Graduate School for Biomedical Sciences. Dr. Preston's research and current activities have focused on the mechanisms of radiation and chemical carcinogenesis and the approaches for incorporating these types of data into cancer risk assessments.

Dr. Preston was chair of Committee 1 of the International Commission on Radiological Protection (ICRP), a member of the ICRP Main Commission, and a member of the U.S. delegation to the United Nations Scientific Committee on the Effects of Atomic Radiation. He is an associate editor of *Environmental and Molecular Mutagenesis, Mutation Research, Chemico-Biological Interactions, and Health Physics*. Dr. Preston has had more than 200 peer-reviewed papers and chapters published. He received his BA and MA from Peterhouse, Cambridge University, England, in genetics and his PhD from Reading University, England, in radiation genetics. He has served on the National Research Council's Committee to Assess the Scientific Information for the Radiation Exposure Screening and Education Program and the Task Group on the Biological Effects of Space Radiation.

Ehsan Samei, *Speaker*, is a Persian-American medical physicist. He is a tenured Professor of Radiology, Medical Physics, Biomedical Engineering, Physics, and Electrical and Computer Engineering at Duke University. He serves as the Director of the Duke Medical Physics Graduate Program and the Director of the Clinical Imaging Physics Group. His interests and expertise include x-ray imaging, theoretical imaging models, simulation methods, and experimental techniques in medical image formation, analysis, assessment and perception. His current research includes methods to develop image quality and dose metrics that are clinically relevant and that can be used to design and utilize advanced imaging techniques towards optimum interpretive and quantitative performance. He has an active interest in bridging the gap between scientific scholarship and clinical practice, in the meaningful realization of translational research, and in clinical processes that are informed by scientific evidence. He has mentored over 100 trainees, has published over 230 referred journal papers, and been the recipient of 34 extramural grants.

Biographies

J. Anthony Seibert, *Speaker*, is Professor of Radiology at the University of California (UC) Davis School of Medicine in Sacramento, California. He received a PhD in Radiological Sciences from UC Irvine in 1982, specializing in quantitative digital fluoroscopic imaging. Directly thereafter, he took a faculty position at UC Davis Medical Center, pursuing digital imaging research, physics education efforts for graduate students and radiology residents, as well as quality control for medical imaging equipment in diagnostic radiology.

He is the Associate Chair of Imaging Informatics for the Department of Radiology, with continuing academic interests in digital mammography; computed tomography; interventional radiology; imaging informatics; and radiation dose tracking, assessment and reporting. Former president of the American Association of Physicists in Medicine (AAPM) in 2011 and current Trustee of the American Board of Radiology, Dr. Seibert has served and continues to interact with many professional committees in regards to medical imaging issues and presenting technical / educational events for AAPM, the International Atomic Energy Agency, and other professional societies. For NCRP, he is a member of Program Area Committee 4. As a co-author of *The Essential Physics of Medical Imaging* textbook for diagnostic physics education, Dr. Seibert continues with the development of cutting-edge imaging technologies and medical physics education to improve the state of imaging science for the betterment of patient care.

George Sgouros, *Speaker*, focuses on modeling and dosimetry of internally administered radionuclides with a particular emphasis on patient-specific dosimetry, alpha-particle dosimetry, and mathematical modeling of radiopharmaceutical therapy. Dr. Sgouros' laboratory is currently engaged in preclinical research investigating targeted alpha-emitter therapy of metastatic cancer and clinical research examining the impact of patient-specific treatment planning on treatment outcome. He is author on more than 140 peer-reviewed articles, as well as several book chapters and review articles. He is chairman of the Medical Internal Radionuclide Dose Committee of the Society of Nuclear Medicine and Molecular Imaging. He has served as chairman of the Dosimetry and Radiobiology Panel at a U.S. Department of Energy workshop on alpha-emitters in medical therapy and, in the early 1990s, provided the physics/dosimetry support for the first U.S. Food and Drug Administration approved human trial of targeted alpha-emitter therapy. He is also a member of the International Commission on Radiation Units and Measurements Report Committee on *Bioeffect Modeling and Equieffective Dose Concepts in Radiation Therapy* and chair of Report Committee 31 on *Treatment Planning for Radiopharmaceutical Therapy*. He is a member of the Scientific Committee of the International Atomic Energy Agency/World Health Organization Network of Secondary Standards Dosimetry Laboratories and a member of NCRP. Dr. Sgouros was a member of the National Institutes of Health study section on Radiation Therapeutics and Biology (RTB) from 2013 to 2017 and chair of RTB from 2015 to 2017. Dr. Sgouros is the recipient of the Society of Nuclear Medicine and Molecular Imaging Saul Hertz Award which honors outstanding achievements and contributions in radionuclide therapy.

Keith J. Strauss, *Speaker*, is an Associate Professor at the University of Cincinnati School of Medicine and the Head of the Section of Clinical Medical Physics within the Radiology Department of Cincinnati Children's Hospital Medical Center. Mr. Strauss received a BA degree in physics from the University of Manchester and an MSc degree in radiologic physics from the University of Chicago. He began his career as a Diagnostic Medical Physicist at Michael Reese Hospital in Chicago before focusing on pediatric radiology in Boston and Cincinnati since 1984.

Mr. Strauss' research interests are predominantly focused on altered clinical configurations of x-ray imaging equipment designed to manage the pediatric patient's radiation dose while maintaining good quality imaging. International affiliations include the International Atomic Energy Agency and pediatric hospitals associated with Project HOPE. Mr. Strauss is active on committees within the American Association of Physicists (AAPM) in Medicine and American College of Radiology (ACR). He is currently the Vice Chair of the Image Gently® Alliance and a Fellow of ACR and AAPM.

Bruce Thomadsen, ***Speaker***, began his practice of medical physics in 1970. After a residency at Henry Ford Hospital, working at Hurley Hospital in Flint, and stint as the Chief Medical Physicist at St. Barnabas Medical Center in Livingston, New Jersey, he settled into the University of Wisconsin, where he remained for 42 y. His practice has spanned from small community hospitals to a large university in the fields of physics for radiotherapy, nuclear medicine, radiology, and health physics.

Mr. Thomadsen has served the radiological community through participation in many committees for various societies. He has chaired the Advisory Committee on Medical Uses of Isotopes for the U.S. Nuclear Regulatory Commission and is the President of the American Association of Physicists in Medicine.

Julie E.K. Timins, ***Program Committee/Session Co-Chair***, is a Diagnostic Radiologist, board-certified in General Radiology and in Nuclear Medicine. Her medical practice has been varied, including Chair of Nuclear Medicine at the Veterans Administration Hospital in Lyons, New Jersey; 10 y as Staff Radiologist at Robert Wood Johnson University Hospital, New Brunswick, New Jersey; 11 y in an inner-city hospital in Jersey City; and over 4 y in a suburban out-patient imaging facility specializing in Mammography and Women's Imaging in Morristown, New Jersey. Dr. Timins is Chair of the New Jersey Commission on Radiation Protection, and sits on the New Jersey Radiologic Technology Board of Examiners. She served on the NCRP Board of Directors, and received a Commendation for Outstanding Service on the 2010 Annual Meeting Program Committee – "Communication of Radiation Benefits and Risks in Decision Making." She is past president of the Radiological Society of New Jersey and recipient of that organization's Gold Medal Award. Dr. Timins was honored as a Fellow of the American College of Radiology, and has served that organization on the Council Steering Committee and as Chair of Practice Guidelines and Technical Standards, on the Commission on Quality and Safety.

She is a recipient of the Advisory Committee Service Award of the U.S. Food and Drug Administration, in recognition of distinguished service on the National Mammography Quality Assurance Advisory Committee. The American Association for Women Radiologists has honored Dr. Timins with the Professional Leadership Award for Mid Career/Senior Faculty and the President's Award. In appreciation of service as an Affiliate Member of the Conference of Radiation Control Program Directors, she was presented with the Board of Directors Award for Outstanding Achievement in the Field of Radiation Protection, for participation on the H-30 Task Force and development of the White Paper on *Bone Densitometry*.

Jessica S. Wieder, ***Speaker***, is the Associate Director of the U.S. Environmental Protection Agency's (EPA) Center for Radiation Information and Outreach. Ms. Wieder was the EPA's radiation communication lead during the response to the 2011 Fukushima Daiichi nuclear accident. She has facilitated international panels on radiation risk public communication and was part of the contingency planning team for the 2011 launch of the Mars Science Laboratory. In 2010, Ms. Wieder was detailed to the Federal Emergency Management Agency's (FEMA) Chemical, Biological, Radiological, Nuclear and Explosives Branch, where she helped establish FEMA's Improvised Nuclear Device Response and Recovery Program and created the intergovernmental Nuclear/Radiological Communications Working Group. With her guidance, the working group developed the nuclear detonation messaging document *Improvised Nuclear Device Response and Recovery: Communicating in the Immediate Aftermath*. Ms. Wieder was also the lead author for the communications chapter for the second edition of the White House's *Planning Guidance for Response to a Nuclear Detonation*. In 2013, Ms. Wieder was awarded EPA's Exemplary Customer Service Award for her leadership in enabling all levels of government to provide quick, effective communications to the American people in response to large-scale radiological emergencies.

Biographies

X. George Xu, *Speaker*, received a PhD in Nuclear Engineering from Texas A&M University (College Station) in 1994. He has been on the faculty of Rensselaer Polytechnic Institute (Troy, New York) for the past 23 y, currently holding the Edward E. Hood Chair of Engineering. Dr. Xu has mentored more than 40 PhD and MS students. His research focuses on computational and experimental methods for radiation dosimetry for radiation protection, medical imaging, and radiotherapy. In the past 20 y, his research has been continuously funded by the National Science Foundation (NSF), the U.S. Department of Energy, the National Institute of Standards and Technology, and the National Institutes of Health. Dr. Xu has authored 160 peer-reviewed papers, 400 conference abstracts, and 120 invited talks. He is the co-editor for *Handbook of Anatomical Models for Radiation Dosimetry* published in 2009 and the author of several comprehensive review articles. Dr. Xu is a fellow of the American Nuclear Society (ANS), the Health Physics Society, and the American Association of Physicists in Medicine. Among his awards are the NSF Faculty CAREER Award, ANS Radiation Protection and Shielding Division's Professional Excellence Award, and the Council on Ionizing Radiation Measurements and Standards' Randal S. Caswell Award for Distinguished Achievements.

Pat B. Zanzonico, *Program Committee/Session Co-Chair*, received a BS in Physics from Cooper Union in 1977 and a PhD in Biophysics from the Cornell University Graduate School of Medical Sciences in 1982. He served on the faculty of the Department of Radiology (Nuclear Medicine) of the New York Hospital-Cornell Medical Center and is currently a Member and Attending Physicist at Memorial Sloan Kettering Cancer Center, Co-Head of the Center's Small-Animal Imaging Laboratories, and Chairman of its Committee on Radiation. He also serves on the Special Contributing Faculty of the Gerstner Sloan Kettering Graduate School and is an Adjunct Professor of Applied Physics and Mathematics at Columbia University. Dr. Zanzonico is Associate Editor of the *British Journal of Radiology* and the *European Journal of Nuclear Medicine* and a member of the Editorial Boards of the *Journal of Nuclear Medicine* and *Medical Physics*. He is also a member of the Medical Internal Radionuclide Dosimetry Committee of the Society of Nuclear Medicine and Molecular Imaging and Vice-Chairman of the U.S. Nuclear Regulatory Commission's Advisory Committee on Medical Uses of Isotopes, and a past Consultant to the International Atomic Energy Agency. Dr. Zanzonico has over 120 peer-reviewed publications and over 75 invited presentations. He is actively involved in biomedical research on radionuclide-based methods for detecting and localizing tumor hypoxia, immune effector-cell trafficking, patient-specific dosimetry for radionuclide therapies, and small-animal and molecular imaging.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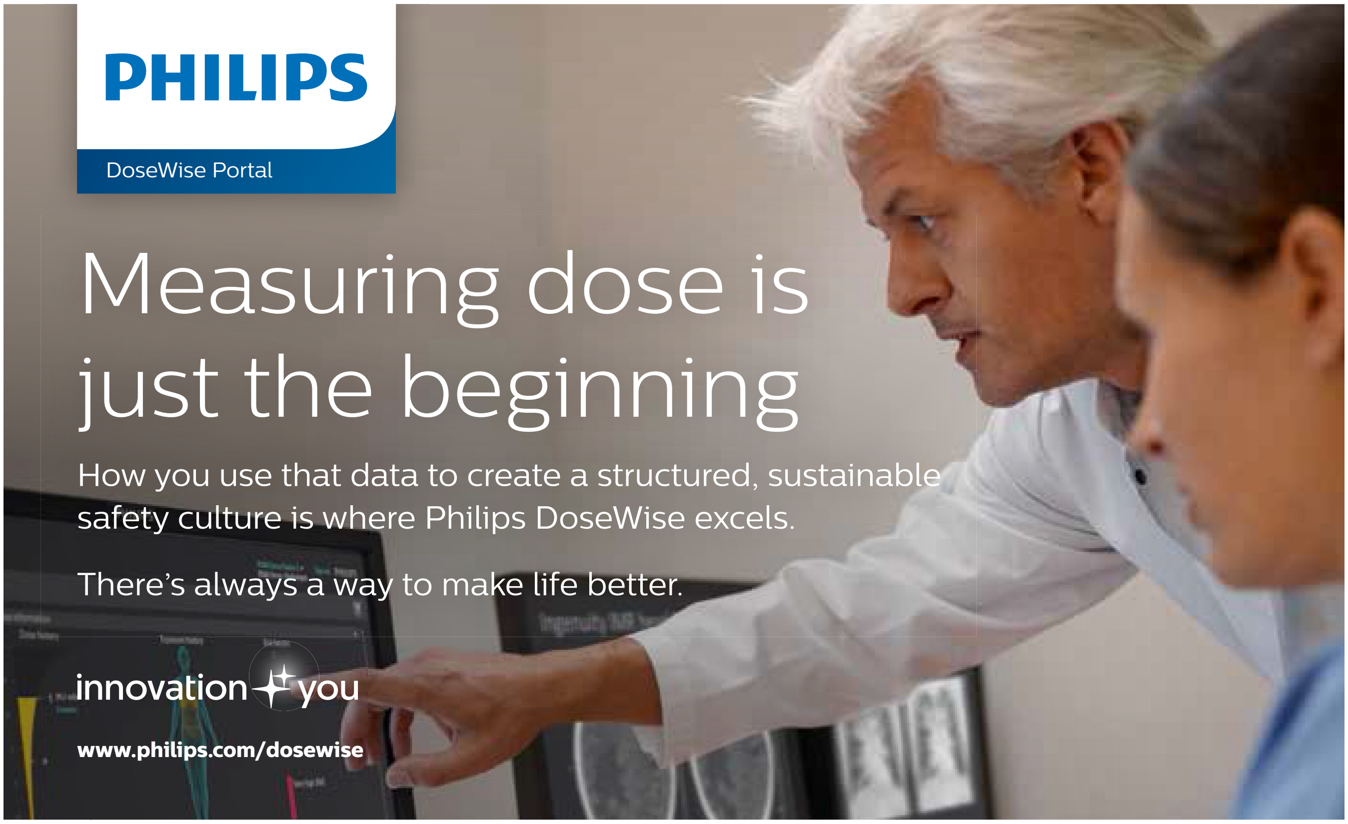
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