RSNA/AUR/APDR/SCARD Radiology Education Research Development Grant

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NOTE: Personal information for the applicant and other investigators has been removed from this sample application.

Title:
Training the Trainers: How to Answer Radiation Biology Questions Before, During, and Following a Radiation Terrorism Event

Abstract:
Many authorities recognize the increasing likelihood of the occurrence of a terrorist-generated radiological or nuclear event. In order to develop successful response plans, emergency personnel (hospital staff, first responders, etc) need to have received a primer in radiation biology so they can adequately recognize, and respond confidently to, a radiological event and know how to get adequate assessment and support. The onus for this education falls on many of those currently employed within the radiological fields, who themselves may lack a full understanding of the biological underpinnings of such an event. We propose to develop a new and comprehensive course, provided by some of the leading radiation biologists in the U.S. that can be distributed and used to "train-the-trainers" in the fundamentals of relevant radiation biology topics. This course will form a useful part of a toolkit to educate both media and public in the event of a radiological emergency.

This grant will enable the creation of a unique multidisciplinary educational resource that will not only serve the broader community in preparation for a response to a terrorist incident, but also will serve as a valuable and concise summary of the pathways of radiation interactions and injury.

Other Investigators:
Each of the investigators will be responsible for preparing a one hour-long lecture, with accompanying notes and audio commentary that will collectively serve as a new and comprehensive educational tool covering aspects of radiation biology as they relate to radiological and/or nuclear terrorism.

- Stephen Brown, PhD, Associate Professor, Department of Radiation Oncology, Wayne State Medical School, Detroit, MI
- Alan D'Andrea, MD, Fuller-American Cancer Society Professor, Department of Radiation Oncology, Harvard Medical School, Cambridge, MA
- Joel Greenberger, MD, Professor and Chairman, Department of Radiation Oncology, University of Pittsburgh Medical Center, Pittsburgh, PA
- Eric Hall, PhD, Higgins Professor of Radiation Biophysics and Director, Center for Radiological Research, Columbia University, New York, NY
- William McBride, DSc, Professor and Vice Chair for Experimental radiation Oncology, Department of Radiation Oncology, University of California, Los Angeles, CA
- Jeffrey Schwartz, PhD, Associate Professor, Department of Radiation Oncology, University of Washington, Seattle, WA
- Jacqueline Williams, PhD, Research Associate Professor, Department of Radiation Oncology, University of Rochester School of Medicine and Dentistry, Rochester, NY

Detailed Education Research Plan:

Introduction
Rationale and Purpose:

It has been recognized for some time that the United States lacks a comprehensive strategy for countering the threat of terrorism from chemical, biological, radiological or nuclear weapons (1). This failing has become more critical in light of recent developments in the geopolitical climate, since it now appears to be increasingly likely that a terrorist-generated radiological or nuclear event could occur within the United States (2). Some of the possible scenarios that have been suggested include: i] the theft and detonation of a nuclear device; ii] the theft or purchase of material leading to the detonation of an improvised nuclear device (IND); iii] an attack against a nuclear facility, e.g. a nuclear power plant, leading to radioactive particle dispersion; iv] detonation of a radiological dispersion/emission device (RDD or RED), the so-called "dirty bomb"; and finally, v] as recent events have shown, a non-explosive dispersion event, which could involve either rapid or slow release of radiation, the former exemplified by the radioactive particle contamination of multiple personnel and sites in the UK and the latter being a more insidious contamination, designed to cause mass panic rather than actual physical injury. Although these scenarios have different levels of probability of occurrence, nonetheless there is a high likelihood that the United States will have to face one of them in the foreseeable future.

Irrespective of the level of the incident, as has been seen from the medical responses to many of the recent incidents involving radiation, notably the U.K. polonium poisoning and the Thailand scrap-yard contamination incident, the vast majority of general, and even emergency, practitioners have little understanding of the health consequences of radiation exposure. In addition, they have difficulty in recognizing and diagnosing symptoms, critically delaying the administration of possible life-saving treatments. Even when radiation is rapidly identified as the source of injury, the bulk of the medical community is uncertain of the medical management of exposed individuals (3). To this end, an increasing number of documents and specific websites (e.g. the Armed Forces Radiobiology Research Institute [AFFRI; www.afrri.usuhs.mil/] and the Radiation Emergency Assistance Center/Training Site [REAC/TS; http://orise.orau.gov/reacts] are available that are targeted at offering assistance to the medical community in the event of a radiation emergency (4). However, it may be even more critical that emergency responders and health care providers are themselves not unduly nervous of the relatively low levels of radiation to which they may be exposed, since an incomplete understanding of the risks posed by radiation can result in an unreasonable fear of cross-contamination, leading to absenteeism and dereliction of duty (5, 6). Such an understanding will require more than the simple presentation of a literature on radiation effects; medical education and training programs need to be expanded to provide easily understood information that includes the science behind radiation effects, allowing for a more informed awareness of the risks and, therefore, a more rational and controlled response to an incident (7). This training, of necessity, will need to be provided by those currently working in radiological and health physics areas and the course that we propose to develop is designed to offer an educational tool to those personnel who will be providing just such information to the medical community, and should be of use at all levels of training.

Of additional concern is the fact that, despite the significant differences in the likely aftermath from each of the above scenarios, one element that is consistent in all would be the involvement of the “worried well” in the targeted population and the psychological consequences to the population as a whole that are often the result of such an event. For instance, If we consider the Chernobyl accident as the most appropriate modern example of a large-scale radiation incident, it already has been demonstrated that there can be an enormous impact on the affected community’s behavior as a result of a lack of information and education regarding radiation effects. The United Nations-sponsored Chernobyl Forum has identified an increase in psychological problems in the affected population as a significant after-effect; these problems were compounded by insufficient communication about radiation effects (8). Indeed, in the WHO report that was part of the same series, it was stated that the “mental health impact of Chernobyl is the largest public health problem unleashed by the accident to date" (9). It has been recommended strongly by a number of authorities that efforts be made to provide the public, and more especially key professionals, with accurate information about the health and mental health consequences of such a radiation-related disaster (10). This need is further underscored by the level of mistrust that is still demonstrated by the population affected by Chernobyl towards authorities, a mistrust that is a consequence of the use of conflicting data by different institutions, unresolved controversies surrounding the impact of low-dose radiation on health, and the often complex scientific language that is used to present the information (9). It is therefore apparent that, in the event of a nuclear or radiological terrorist event, many professionals from a wide spectrum of radiological sciences will be called upon to address the public on health risks and available countermeasures, and a consistent and simple message that is clearly understood by the majority of the public would be of enormous benefit (11). We intend for the proposed course to be designed to provide critical material to such spokesmen in the form of explanations of our current understanding of the radiation biology as it relates to radiation accidents, the effects of low dose levels of radiation and, in addition, the current status and availability of assessment tools and mitigating agents. Importantly, we intend that this course will be specifically aimed at providing such spokemen, who will in all likelihood be professionals drawn from the radiological sciences, with the material to be able to clearly convey these complicated ideas to not only concerned medical staff, but also the general public.

Objectives:
This course is designed to “train-the-trainer,” providing a series of lectures and notes that can be used as:

i. a refresher in basic radiation biology fields that have relevance not only to those involved in radiation therapeutic fields, but more importantly to those that may participate in casualty management following a radiological or nuclear event;
ii. a primer for those who may be called upon to answer radiation questions that can arise prior to and/or following radiation-related accidents and also can be used as a reference in training and media presentations;
iii. material that can be used in subsequent lectures by the trainers themselves.

It is anticipated that this material will be made available to potential users through the websites of such bodies as RSNA and other relevant venues, and will be made freely available in CD format.

Student Population:
We anticipate that this course will provide material for radiologists and personnel in related disciplines, but particularly those that are currently involved, or may become involved, in education and training. In this context, “education” is defined as the teaching/explaining of radiation biology principles to, not only radiologists and radiation oncologists, but also other hospital staff, such as emergency personnel, first responders such as EMTs, firemen and police, the public media, and local authorities. The student population also could include radiation oncologists, health physicists and occupational safety personnel, all of whom may be called on following a nuclear or radiological accident or terrorist event.

Previous Experience:
The Principal Investigator is a leading radiation biologist with a national and international reputation in the field of radiation-induced normal tissue late effects. Dr. Robbins obtained a BSc (Hons.) degree in Applied Biology in 1976 and a PhD in Renal Physiology in 1980 at Thames Polytechnic, London, UK. He then obtained an appointment in the Cancer Research Campaign (CRC) Normal Tissue Radiobiology Group, Churchill Hospital, and University of Oxford, Oxford, UK under the direction of John Hopewell, PhD. In 1987, he was promoted to Deputy Director of the CRC Normal Tissue Radiobiology Research Group, a position he maintained until moving to the US in 1993 as Associate Professor and Director of Research in the Radiation Research Laboratory of the Department of Radiology at the University of Iowa. He was promoted to Full Professor in 2000, and moved in September 2001 to take up his current appointment as Professor and Head, Section on Radiation Biology, Department of Radiation Oncology at WFUSM. He is an Overseas Editor for the British Journal of Radiology, a member of the Editorial Board of the International Journal of Radiation Biology, and Associate Editor for the Radiation Research journal, the official journal of the Radiation Research Society. Dr. Robbins has extensive educational expertise in radiation biology. He has mentored 4 MS and 4 PhD graduate students, as well as 7 postdoctoral fellows. Dr. Robbins currently serves as mentor for three PhD candidates in the Cancer Biology Graduate Program, as well as 2 postdoctoral trainees. Dr. Robbins

has created a didactic course in Radiation Biology (Introduction to Radiation Biology CABI 715) in the Cancer Biology Graduate Program. Moreover, he serves as the PI on an NCI-funded T32 Postdoctoral Training Program in Translational Radiation Oncology that is funded from 7/1/05-6/30-10.

Of note, Dr. Robbins' entire team of co-investigators has similar reputations in their respective radiobiological areas, both in research and education. For example, Dr. Eric Hall is the author of one of the most widely used sources for radiation biology education, "Radiobiology for the Radiologist", a book currently in its sixth edition, as well as books for the general public such as "Radiation and Life" and "Making the Radiotherapy Decision." Dr. Hall has received both the Gold Medal and the Researcher of the Year awards from RSNA and developed a web-based course in radiobiology that is available on the RSNA web-site. Dr. William McBride is the current President of the Radiation Research Society, the primary scientific organization for basic scientists and clinicians in the area of radiation biology, chemistry, and physics. Dr. McBride is responsible for the teaching of 3 courses in radiobiology (2 graduate, 1 resident) annually at UCLA. He is an ABR Board examiner in radiobiology and a long-time RSNA grant reviewer. This expertise provides the project with an outstanding panel of educators.

Project Plans

Activities:

We plan to develop a new and comprehensive educational tool that covers aspects of radiation biology as they relate to radiological and/or nuclear terrorism. The aim of this proposal is to develop a course that will consist of 8 hour-long lectures, with accompanying notes, each one provided by an acknowledged expert in the field, which can be used as a "train-the-trainer" tool. Many of the lectures also will have utility with respect to cancer therapy and, therefore, the course has a broader relevance outside of the terrorism arena. The hour-long lectures will consist of a series of PowerPoint slides and accompanying notes that will provide a full commentary and explanation of each slide, as well as any relevant references that may be of use to the trainer/viewer. Each individual lecture also will be designed to "stand alone" with respect to its chosen topic, although the series will be edited such that the course can be viewed as a continuum.

The first and introductory lecture will be from the Principal Investigator, Dr. Michael Robbins (WFUSM), and is entitled: *"Impact of a radiological/nuclear device on a community and its emergency services."* This lecture will provide an introduction as to "what is radiation?", the various types of ionizing radiation and their radiobiological properties, as well as how to protect oneself against these forms of radiation. Using a combination of experimental data and human data from the A-bomb survivors as well as victims of accidental radiation exposure, the biological effects of radiation will be reviewed in terms of the different radiation-induced syndromes observed following accidental exposure. These consist of the prodromal radiation syndrome, the cerebrovascular syndrome, the gastrointestinal syndrome, and the hematopoietic syndrome. The dose-and time-dependent aspects of the various radiation syndromes will be explained using fundamental radiation biology principles. The medical consequences of a radiological/nuclear device will then be discussed, along with the importance of triaging exposed individuals based on their likely radiation dose exposure. Medical management, including supportive care, transfusions and stem cell transplant will also be reviewed.

The second lecture, by Dr. William McBride (UCLA), is entitled: *"Death versus survival"* and will provide an overview of the most fundamental consequence of radiation in biology, that is, cell lethality. For radiobiologists in general, it is necessary to integrate the classic scientific findings on cell death and survival with our modern understanding of molecular pathways if rational strategies for increasing the therapeutic benefit in cancer treatment are to be devised. Obviously, those engaged in assessing and combating the effects of acute radiation injury following a radiological or nuclear accident also require a similar understanding. For example, it has been known since the 1950s that certain cell types, most notably lymphocytes, can die rapidly following irradiation, normally within 3-6 hours. This can occur during interphase without progression into or around the cell cycle and is observed after even very low doses of radiation. We now recognize this death to be apoptotic in nature; since it is rapid and universal, this phenomenon has found some utility as a biodosimeter. In contrast, other cell types, which are in the majority, typically can execute one or more attempts at cell division, even if they are lethally injured, before undergoing "mitotic death". The number of successful divisions depends upon the size of the radiation dose. After 2 Gy, the average number of divisions is around 2.5, whereas after 6 Gy, it is closer to 1.5. Since each division increases the chances of some of the progeny surviving, even if most cells die, this can influence clonogenic cell survival. Importantly, such information can form the basis for biodosimetric techniques as well as developing medical countermeasure strategies aimed at improving acute survival. These and other consequences of cell death, such as tissue and organ tolerance, will be discussed.

The third lecture, entitled: *"Oxidative stress and radiation biology,"* comes from Dr. Joel Greenberger and his group from the University of Pennsylvania School of Medicine. Dr. Greenberger is Professor and Chair, Department of Radiation Oncology, and Deputy Director of the Lung Cancer Center of the University of Pittsburgh Cancer Institute, Pittsburgh, PA. Dr. Greenberger is world-renowned for his research into the role of antioxidant enzymes in modulating radiation-induced injury. This lecture will review current knowledge with respect to the complex oxidative stress events involved in the response to ionizing irradiation. A central and critical part of this lecture will focus on the similarity and overlap between ionizing irradiation-induced oxidative stress events, and those associated with other forms of cytotoxic killing, e.g. non-specific inflammation, infection, and the injury response to other forms of tissue and organ damage. There is increasing evidence that a major component of both radiation damage and repair is dependent upon the redox status of cells, tissues, and organs. Total cellular and organ-specific (mitochondrial-specific) levels of total thiols, glutathione, and specific antioxidant defense pathways (including superoxide dismutases, catalase, glutathione peroxidase, and other antioxidant enzymes) combat and neutralize the initial and chronic production of free radicals initiated by the radio-chemical events of ionizing irradiation. Initial induction of superoxide, hydroxyl radical, liberation of electrons, and secondary and tertiary electrons is followed by rapid phosphorylation of the ATM cascade and molecular biologic events leading to nuclear to mitochondrial transport of stress activated protein kinases. The molecular events associated with both apoptotic and non-apoptotic death, the initial and secondary induction of inflammatory cytokines, and the complex lipid peroxidation changes in nuclear, mitochondrial, and cell membranes are all involved in ionizing radiation damage. A complex antioxidant reserve system, and antioxidant response pathway counter balances these oxidative stress events. While nuclear DNA repair is occurring and after it is completed, signaling events between nucleus and mitochondria and events between cells in the tissue, and systemic cytokine events within organs and throughout the circulation, continue to occur, and mediate the continuing events in the acute ionizing irradiation response. This lecture will also discuss the potential of oxidative stress products and related components as targets for therapy as well as countermeasures against radiation injury.

The fourth lecture comes from one of the leading bone marrow transplant centers in the U.S. Dr. Jeffrey Schwartz, Associate Professor, Department of Radiation Oncology, University of Washington, WA, and a radiation biologist at Fred Hutchinson Cancer Research Center, will provide a lecture entitled: *"The role of bone marrow transplantation in a radiation incident: current and future."* As many are aware, the key target for moderate to high dose radiation exposure is the bone marrow, and bone marrow suppression can be observed following doses as low as 1-2 Sv. Indeed, the LD50/60 of 3-4 Sv for human exposures is based on bone marrow toxicity. Following exposure of doses between 2 and 8 Sv, patients will show a loss of circulating blood elements because of the death of some or all of their mitotically active precursor cells, and symptoms from this bone marrow syndrome are seen 3 or more weeks after irradiation. Presently available treatments for exposures of less than 10 Sv include antibiotics, platelet infusions and hematopoietic stem cell transplantation (HSCT). Dr. Schwartz will discuss newer approaches that are being developed, including the use of cytokine-based therapies and committed progenitor transfusion. Importantly, it is hoped that these eventually can be stockpiled for use in emergencies since the current approaches, in particular HSCT, tend to be expensive and labor-intensive. In addition, he will discuss approaches such as the use of stem cells from cord blood and HLA-haploidentical cells that might provide less expensive alternatives to standard HSCT.

The fifth lecture, by Dr. Alan D'Andrea (Dana-Farber Cancer Institute, Harvard Medical School) will be entitled *"The DNA damage response: implications for biodosimetry and radioprotection".* Dr. D'Andrea, through his longstanding interest in rare human genetic diseases, such as Ataxia Telangiectasia (AT) and Fanconi Anemia (FA), has developed a signal transduction model for the cellular response to radiation. Dr. D'Andrea has significant collaborations with several other Harvard Medical School faculty members, including Stephen Elledge, Peter Sicinski, Brendan Price, and Bruce Demple. Dr. D'Andrea's lecture will include highlights from these collaborations. Specifically, his talk will describe key DNA damage response proteins (biomarkers), which serve as quantitative signals of a radiation exposure and are therefore useful in biodosimetry. Also, he will describe the identification of novel target proteins, through siRNA and drug screening programs, and the identification of lead compounds for radioprotection.

At this point, the series will transition from the acute radiation response and its mitigation to more downstream events, and the next lecture (#6) is by Dr. Jacqueline Williams from the University of Rochester, and is entitled: *"Assessing and ameliorating late tissue damage following low doses of radiation."* Dr. Williams, Research Associate Professor, Department of Radiation Oncology, University of Rochester School of Medicine and Dentistry, Rochester, New York, and Program Director of Radiation Medicine, Center for Disaster Medicine and Emergency Preparedness, Rochester, New York, has an international reputation in the pathogenesis and treatment of radiation-induced late effects, particularly in the brain and lung. In this lecture, Dr. Williams will discuss our current understanding of the molecular and pathologic changes that lead to the development of radiation-induced late effects. The majority of these delayed effects, which have been recognized in multiple organs and tissues, are a consequence of therapeutic radiation treatment, but also have been recognized in populations exposed to the low dose levels associated with radiation-related accidents through the increased incidence of such conditions as cataracts, and fibrosis-related skin and lung diseases. A large body of work, conducted by Dr. Williams and other investigators in this field, has identified a number of signaling molecules (cytokines, chemokines, and/or growth factors) that are expressed in response to radiation injury at all dose levels. Importantly, irradiation causes an almost instantaneous upregulation of specific proinflammatory cytokines; of note, this direct induction may have some utility as a biodosimeter in a mass casualty situation, which will form part of this lecture's discussion. Downstream, there is further activation of inflammatory and fibrogenic pathways, with a broad spectrum of signaling molecules being expressed in a dysregulated fashion, persisting until the pathological development of the late effect, in a process that has been termed a "perpetual cascade." This lecture will examine the role that these molecules play in the progression towards late effects, the possibility of their use as targets for mitigation and prevention, and the relationship between early expression of cytokines, etc, and the ultimate development of late effects.

Many victims of radiation accidents receive doses that are not associated with the defined acute radiation syndromes, but, nonetheless, will suffer from toxic effects due to injury to critical organs and tissues. Dr. Stephen Brown, Associate Professor, Department of Radiation Oncology, Wayne State Medical School, Detroit, MI, has over 15 years experience in radiation biology research, including gene therapy, sensitization of tumors, and modulation of late radiation-induced injury. Dr. Brown will provide discussion on this subject in a lecture (#7) entitled: *"Organ (lung, kidney and brain) response to radiation and the potential role of ACE inhibitors for mitigating injury,"* and will describe the respiratory dysfunction, renal failure and neurological deficits that are likely to occur in terrorism victims having partial-body radiation doses of 9, 5, and 2 Gy, respectively. Pre-clinical evidence will be presented supporting a new paradigm of chronic radiation-induced late normal tissue morbidity illustrating that a window of opportunity exists for treating radiation injury in the weeks and months after the exposure. One of the most promising approaches is suppression of the renin-angiotensin system with angiotensin-converting enzyme (ACE) inhibitors and angiotensin II receptor antagonists having a benefit on radiation pneumopathy, radiation nephropathy and radiation-induced CNS injury.

The final lecture (#8) is from Dr. Eric Hall (Columbia) and deals with the most widely feared of radiation's late effects; it is entitled: *"Radiation carcinogenesis".* It is widely acknowledged that the most significant long-term consequence of exposure to low doses of radiation is the induction of leukemia and solid cancers. Information on radiation carcinogenesis comes principally from (a) the survivors of the A-bomb attacks on Hiroshima and Nagasaki, and (b) exposure to medical radiation, especially second malignancies in patients following radiotherapy. The A-bomb survivors have been carefully studied for over 60 years and provide quantitative estimates of the risk of radiation-induced leukemia and carcinomas in multiple sites following total body exposure up to about 2.5 Sv. The lowest dose at which an excess incidence can be detected is controversial, but is in the range of 30 to 200 mGy. The data also show very clearly a dramatic variation of radiosensitivity with age, young children being about 15 times as sensitive as late middle-aged adults. In most cases, it is difficult to obtain a meaningful estimate of the incidence of second malignancies in radiotherapy patients because an appropriate control group does not exist. Exceptions include cancer of the prostate and cervix, where patients receiving surgery represent a control group. In those instances where studies are possible, it is clear that there is an excess incidence (small but statistically significant) of sarcomas in or near the treatment field, in addition to an excess of carcinomas in tissues receiving low doses remote from the treatment site, as well as in the high dose regions close to the treatment volume. The radiotherapy patients provide data concerning the effect of exposing a limited volume of tissue to very high doses of radiation, in contrast to the A-bomb survivors, which involve a total body exposure to low to intermediate doses. In summary, we have good quantitative data in humans for carcinogenesis and leukemogenesis over a wide range of doses of low linear energy transfer (LET) radiation. By contrast, we have little or no human data for carcinogenesis by high LET radiation. This lecture will discuss the range of radiation LETs that may occur in a radiological accident or event and the relative long-term risks of carcinogenesis from them.

Time Schedule:
Following the award of the grant in July 2007, each of the co-investigators will edit and finalize their slide material and forward to Dr. Robbins. We anticipate receipt of all of the draft lecture material by September 1, 2007. Dr. Robbins and his Administrative Secretary will edit and coordinate the slides so as to minimize overlap of material and provide continuity between the lectures. We anticipate return of the edited slides to the co-investigators by approximately October/November 2007. Each of the co-investigators will then be asked to finalize their slides with respect to the PI's comments, and prepare their accompanying lecture notes. All material will then be returned to Dr. Robbins by February 2008 for final editing and coordination of slides and notes and preparation of the evaluation questionnaire. We will take the PowerPoint files and utilize a program called PointeCast. (http://www.pointecast.com/) to import voice-over audio files that the PI and Co-Investigators will have recorded from script or notes. The recordings will be done with a DV camera and microphone or MP3 Mic recorder. The PointeCast program will export the completed audio and PowerPoint slides into a Flash based (SWF) file that can be hosted on websites or authored and setup for a CD for distribution.

We anticipate completion of the course and its provision to websites for distribution by April 2008.

Outcomes:
We anticipate that this course will prove useful to a broad range of disciplines, but will be of particular use to those who may be asked to perform in areas outside of their area of expertise and provide public commentary in a time of emergency. It also will provide a refresher course for those requiring a more up-to-date understanding of radiation biology as it pertains to their everyday work in the radiation field.

Evaluation
We will prepare a questionnaire for distribution with the course. We also will request that the website(s) that offer distribution of the course maintain a record of those institutions or individuals that request the material. Follow-up of all course applicants will be made 4-6 months after distribution of the CD unless the questionnaire has already been returned. Course relevance will be assessed and suggestions for improvements will be sought. Alterations could be made to the CD material on an annual basis.

Bibliography

1. Cilluffo FJ, Cardash SL, Lederman GN: Combating Chemical, Biological, Radiological and Nuclear Terrorism: A Comprehensive Strategy. Center for Strategic and International Studies, Washington DC, 2000.
2. Ferguson CD, Potter WC: The Four Faces of Nuclear Terrorism. Monterey Institute of International Studies, California, 2004.
3. Turai I, Veress K, Günalp B, et al: Medical response to radiation incidents and radionuclear threats. Br Med J 2004; 328: 568-572.
4. Department of Homeland Security Working Group on radiological Dispersal Device (RDD) Preparedness: Medical Preparedness and Response Sub-Group, version 5/1/03.
5. Flynn DF, Goans RE: Nuclear terrorism: Triage and medical management of radiation and combined-injury casualties. Surg Clin N Am 2006; 86: 601-636.
6. Veenema TG, Hellman BD, Walden B, et al.: Factors affecting hospital-based nurses' willingness to respond to a radiation emergency. Accepted for publication, J Emer Nurs, 2006.
7. Smith JM, Ansari A, Harper FT: Hospital management of mass radiological casualties: reassessing exposures from contaminated victims of an exploded radiological device. Health Phys 2005; 89: 513-520.
8. Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine. In: Kinley III D, editor. Chernobyl Forum. Vienna, Austria: IAEA; 2006.
9. Health Effects of the Chernobyl Accident and Special Health Care Programmes. In: Bennett B, Repacholi M, Carr Z, editors. Chernobyl Forum. Geneva: World Health Organization; 2006.
10. González AJ: Lauriston S. Taylor lecture: Radiation protection in the aftermath of a terrorist attack involving exposure to ionizing radiation. Health Phys 2005; 89: 418-446.
11. Pellmar TC, Rockwell S, Radiological/Nuclear Threat Countermeasures Working Group: Meeting Report: Priority list of research areas for radiological nuclear threat countermeasures. Radiat Res 2005; 163: 115-123.

Budget:
Total Project Budget: $7,722

Personnel costs:
- Michael Robbins, Professor and Section Head of Radiation Biology, Department of Radiation Oncology, WFUHS, part time salary compensation, $3,080.
- Darlene Cantrell, Administrative Secretary, Section of Radiation Biology, Department of Radiation Oncology, part time salary compensation, $875.
- Fringe costs: Michael Robbins $3,080 x 12% = $369, Darlene Cantrell $875 x 33% = $288

Supplies: Purchase of 100 CDs and duplication = $3.50/CD = $350
Other: Creative Communications at WFUHS estimate 2 hours for each one jour-long lecture = 16 hours at $80/hour. Total cost = $1,280 To author a CD that has a web browser and testing would take approximately 6 hours @ $80/hour = $480. Shipping costs of FedEx for CD and audio recordings = $1000

Justification:

- Personnel: Dr. Robbins and his Administrative Secretary Ms Darlene Cantrell will edit and coordinate the slides so as to minimize overlap of material and provide continuity between the lectures. We anticipate return of the edited slides to the co-investigators by approximately October/November 2007. Each of the co-investigators will then be asked to finalize their slides with respect to the PI's comments, and prepare their accompanying lecture notes. All material will then be returned to Dr. Robbins by February 2008 for final editing and coordination of slides and notes and preparation of the evaluation questionnaire.
- Supplies: We request funds to purchase 100 CDs on which the training program will be burnt for distribution to interested parties.
- Other: Creative Communications at WFUHS will take the PowerPoint files and utilize a program called PointeCast, pointecast.com, to import Voice over audio files that the PI and Co-investigators will have recorded from script or notes. The recordings will be done with a DV camera and microphone or MP3 Mic recorder. The PointeCast program will export the completed audio and PowerPoint slides into a Flash based (SWF) file that can be hosted on websites or authored and setup for a CD for distribution. Shipping costs of $1,000 are requested to recover the cost of sending the Cds between the PI and investigators, as well as to FedEx these to educational trainees.

Other Sources of Support:
This group of investigators was brought together through their involvement in the education and training cores of the recently awarded U19-funded Centers for Medical Countermeasures following Radiation (CMCRs). Support is therefore available for the development of the individual lectures through the CMCR mechanism. However, the specific proposal of developing an education tool for radiological personnel, combining the expertise from all of the co-investigators, is outside the purview of the CMCR objectives. Therefore, there is no current or pending support for the activity of course development.