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TENTH ANNUAL WARREN K. SINCLAIR KEYNOTE ADDRESS
Questions for Dr. Yamashita

Do you expect any thyroid cancers due to radiation from Fukushima?	No, because of very low or negligible internal exposure of thyroid glands to radioiodines in children by the accident in Fukushima. However, the public concern has pressed for the thyroid ultrasound screening in children that may increase the detection rate of childhood thyroid cancers, many that are indolent and would not necessarily come to clinical attention without the special screening of asymptomatic children.
Have any plans for allowing people to return to the evacuated areas been developed?	Yes, now using the International Commission on Radiological Protection recommendation reference level less than 20 mSv y^{-1}, a step-by-step re-entry plan has been initiated..
What are the plans for changing or modifying Emergency Planning Zones?	Under discussion and soon the Japanese authority such as Nuclear Regulatory Commission in Japan will deliver such planning.
Do you have data on the radiation workers? Can you elaborate on issues with your potassium-iodide policy?	No, but the Tokyo Electric Power Company and Ministry of Health in Japan have such data. The potassium-iodide policy is also now under revision in Japan focusing on predistribution and more extension of the areas prepared.
Could you discuss your control group for the two-million-person Fukushima health survey? Have you considered the unaffected Okinawa population?	Yes, we have already planned to compare the different areas using the control group inside and outside Fukushima, but not in Okinawa.

Would Japan consider allowing NCRP and other scientific organizations to hold meetings within the exclusion zone? This could help to assuage the fears of the public.

Yes, we are welcome to cooperate with NCRP and other international sound organizations to assuage a radiation phobia of the public not only within but also outside the exclusion zone in Fukushima.

OVERVIEW SESSION

Question for Dr. Steven Simon

Has any study calculated the background radiation that was present when the Earth was formed and when living organisms first appeared on the Earth? For example, ^{40}K must have been at a much higher level tens of millions of years ago.

I'm not personally familiar with any studies of the sort you asked about, though information is likely available elsewhere. Study of the radiation environment of the early Earth, which was well before the first organisms arose, lies within scientific disciplines not represented by myself or any of the speakers at the NCRP annual meeting. The early radiation environment of the Earth is of possible interest to paleontologists, evolutionary biologists, and other specialists, though is not considered as fundamental knowledge to present day radiation protection.

Present day science suggests the Earth is about 4.6 billion years old; organisms arose one to two billion years later, while Homo sapiens arose only a few hundred thousand years ago. Modern day radiation protection provides a means to protect the health of present day human populations (though there is some interest in protection of nonhuman species as well). Consequently, radiation protection as a science has developed through studies of human populations who have lifestyles still existing today and who are generally exposed to the same types and sources of radiation.

I'm sorry I cannot answer your question more specifically.

Questions for Dr. Roy Shore

There are cytogenetic and point mutation mechanisms to explain in part the radiation induced leukemia and solid cancers; however what are the postulated mechanisms for producing cardiovascular diseases?

At this point, we know little about the possible mechanisms for induction of cardiovascular diseases at doses on the order of 1 Sv or less. We clearly need more translational and experimental studies to elucidate this.

Should cumulative dose or single exposure dose be treated for the risk associated with radiation situations?

It is generally believed that some function of cumulative exposure is appropriate. The concept of a dose and dose-rate effectiveness factor (DDREF) is often employed to quantitatively factor in how much the additive biological effects of cumulative small doses may be less than those from a single larger dose. However, at this time there is a considerable range of uncertainty as to how large the DDREF may be.

I have read:

1. **no solid cancers found in any epidemiological study attributable to radiation when doses were <0.1 Sv;**
2. **for several sites, atomic-bomb survivor data are compared by dose group rather than to controls because cancer incidents in controls are greater; and**
3. **epidemiological studies of populations residing in areas with high natural background radiation do not find increased incidence of radiogenetic cancer in populations.**

1. Probably the clearest examples of solid cancers found at doses under ~0.1 Sv are for thyroid cancer, as shown in several medical irradiation studies following childhood exposures, and solid cancers seen after *in utero* diagnostic irradiation. The data on solid cancers in the atomic-bomb studies also are suggestive of risk at doses <0.1 Sv but are limited by the studies' low statistical power in that dose range.
2. In the atomic-bomb study the "not in city" (NIC) group is thought to differ from the distally exposed group with regard to various sociodemographic factors (*e.g.*, urban/rural, socioeconomic) that affect baseline cancer risks. Several recent analyses of the atomic-bomb cohort have utilized the NIC group, with statistical adjustment for the noncomparability factors. One also could cite the opposite "effect": the distal survivors have somewhat higher rates of cancer than those of nearby Okayama prefecture, but again, in large part, this probably reflects sociodemographic and other nonradiation factors.
3. As with those mentioned in (2), sociodemographic factors may overshadow possible radiation effects in comparing tumor rates in high- and low-background radiation areas. In addition, there may be concerns about the completeness and comparability of the cancer registries in the corresponding high and low areas.

How do your conclusions (no evidence of nonlinearity and significant dose response ranging from 0 to 150 mGy) account for these seemingly contradictory studies?	As stated in response to (3) above, a number of other factors impinge and lead to uncertainties, but consistent dose-response slopes tend to be less subject to bias than simple exposed/unexposed group comparisons.
Given the large and increasing growth in U.S. medical radiation exposure, how does one correct epidemiological studies of other sources such as environmental or occupational exposures, for example, nuclear power plant workers are relatively well paid and insured and are likely to be able to afford more diagnostic procedures than poorer people living in the same area.	Comparing employed workers with the general population is fraught with potential biases, both in the direction the question mentions and in the opposite direction due to selection of healthy persons for employment (healthy worker effect) and further selection factors for continued employment [healthy worker survivor effect (HWSE)].Those are reasons why exposure-response analyses based on data within the occupational group tend to be more reliable than general population comparisons, especially if special care is taken to examine potential HWSE effects.
The estimation of the percent of the epidemiological study needs to take into account of the power of the study to defeat the significant effects.	Not sure I understand the point. However, a major concern in reviewing low-dose studies is that they may have inadequate statistical power to detect effects, so that there are more false-negative studies than there would be if the studies had the same dose distributions but much larger sample sizes.
When counting the number of low-dose effects, don't we have to consider the issue of publication bias — where negative studies are less likely to be published?	Yes, publication bias can be a concern. That is one reason why my presentation focused on only the largest studies, ones that are less likely to be unpublished even if negative.
In low dose protracted fractionated exposures are there any evidence of protective effects?	Since more than the expected numbers of studies were significantly positive, the "weight of evidence" does not suggest protective effects.

What should the "cut line" be for radiation protection officers to limit computed tomography use by medical professionals? Should more invasive procedures (or magnetic resonance imaging) be considered?	These are obviously policy issues that need discussion by a wide array of experts.
Given that there is a concern with low-dose radiation and health effects, it is unfortunate that limited data from U.S. Department of Energy (DOE) workers (with low-dose exposures) have been presented. Dr. Shore presented three in his "literature" review — Savannah River Site, Los Alamos National Laboratory, and Oak Ridge National Laboratory. Perhaps to further look at this question, the National Institute for Occupational Safety and Health(NIOSH) should also be invited to participate on the future panel?	Actually, considerably more DOE worker studies were presented than those named in the question. Others were included in the 15-country study or in several other references, some of which were NIOSH-based references.
Looking at the high end instead of the low end, of the "linear response" curve, it appears that from one of Dr. Shore's slides on the cancer incidence vs. colon dose in Japan that the curve is starting to end downward. Is there a valid observation, and is it present in relevant animal models?	A number of studies suggest that excess cancer incidence for various sites tends to plateau or taper off at high doses, perhaps due to cell killing or allied phenomena. However, the dose level at which this phenomenon begins varies considerably from study-to-study and tumor site-to-site.

There are reports, although not rigorous epidemiological studies, of post-traumatic stress disorder (PSTD) in atomic-bomb survivors and Fukushima evacuees. So here are the questions:

a. **What is the evidence for a link between PTSD and cardiovascular disease?**
b. **Is there also evidence for increases in inflammatory markers in PTSD (*e.g.*, cytokinetics and C-reactive protein)?**
c. **Are there any studies being done to distinguish between low-level radiation effects and psychological effects that produce physical effects?**

Dr. Bromet is better qualified than I to address these questions, but a reference to a paper may be helpful regarding (**a** and **b**) [Wentworth, B.A., Stein, M.B., Redwine, L.S., Xue, Y., Taub, P.R., Clopton, P., Nayak, K.R. and Maisel, A.S. (2013). "Post-traumatic stress disorder: A fast track to premature cardiovascular disease?," Cardiol. Rev. **21**(1), 16–22].

Regarding (**c**), an atomic-bomb paper [Yamada, M. and Izumi, S. (2002). "Psychiatric sequelae in atomic bomb survivors in Hiroshima and Nagasaki two decades after the explosions," Soc. Psychiatry Psychiatr. Epidemiol. **37**, 409–415] indicated that the survivors did show more psychiatric sequelae (anxiety and somatization symptoms) than those "not in city" at the time of the bombing, but the distal survivors had as much or more of those symptoms than the proximal survivors, suggesting it was not related to radiation dose *per se*, except for those who had had acute radiation symptoms (*e.g.*, epilation, keratoses). That paper also summarizes some earlier reports on psychiatric sequelae of the bombings.

Are there any studies being done to distinguish between low-level radiation effects and psychological effects that produce physical effects?

I do not know of any. We once did a cross-sectional study of solvent exposure, occupational stress, and mental health. In the end, the symptoms associated with the exposures and the stressors were the same and impossible to disentangle with a cross-sectional design. There are no hypotheses at present that would indicate a mechanism to explain a relationship between low-level radiation and psychological effects. There are papers on liquidators who suffered from acute radiation syndrome, but the diagnoses were never independently verified, and the electro-encephalogram findings, if replicated independently, probably would not apply to low-level radiation exposure.

Questions for Dr. Evelyn Bromet

What is the effective treatment of emotional consequences?

A critical issue is early identification of highly exposed and high-risk populations so that interventions can occur at the earliest possible moment to prevent long-term mental health problems from taking root. It is also important to tailor, time and target interventions appropriately. To date, social support and cognitive behavioral therapy are the most effective and the safest interventions for post-disaster mental health problems. However, they have to be designed as long-term, dynamic programs, given the long-term emotional toll of events like the triple disaster in northeast Japan.

What can be done proactively to insulate populations from disaster-related psychological injuries?

In the immediate aftermath, before clinically significant psychiatric symptoms emerge, the recommended prevention approaches are:

1. promote a sense of safety;
2. reduce anxiety;
3. increase self and collective sense of empowerment;
4. encourage social support;
5. instill hope; and
6. provide accurate, timely, clear, and credible information.

It is important to have professionals with good communication skills who can provide clear explanations of the disaster, explain safety procedures, describe the resources available to the population, and be available to answer questions either in person or *via* social media or electronic communication. It is also important that remuneration is provided promptly. High risk groups, such as pregnant women, young mothers, elderly persons, need to have ongoing, accessible support systems in place and open lines of communication with persons in authority and with medical doctors.

How do you support community mental health before, during and after an event?

Different countries have different systems of mental health care. Most individuals around the globe seek counseling for emotional problems from their primary care doctors, not from mental health professionals. One thing that is needed is that medical students and residents learn about the detection and treatment of common psychiatric problems that are endemic in the community and that become more prevalent (or new onsets) after disasters. These include depression, post-traumatic stress disorder or symptoms, and other forms of anxiety, especially health-related anxiety. Clergy also play a key role, depending on where the disaster occurs. There is a growing literature on post-traumatic growth, suggesting that disasters can also promote new-found resilience and strengths.

It is also important to support local leaders who emerge in times of community stress. They are often the most trusted source for the community and are therefore in a position to be of great help to medical providers and other professionals in communicating ways to recover from a disaster and responding to questions from the public.

The most vulnerable of course are people who lost family members, friends and neighbors. Grief counseling by experienced professionals is a critical, long-term part of the recovery process.

Do new nuclear power accidents reignite concerns of additional mental health consequences by exposing individuals to previous accidents (*e.g.*, Chernobyl accident on Three Mile Island individuals)?

Yes. Previous trauma is a predictor of post-trauma mental health problems. This was a concern in our Three Mile Island study because comparison group lived near another nuclear power plant in Pennsylvania that had experienced accidents, although not of similar magnitude. We therefore added a second comparison group who resided near a coal-fired plant. Anecdotally, I was told that many women in Kiev strongly identified with the terror experienced by young mothers living near Fukushima and followed news stories about Fukushima very closely.

Are there significant differences on mental health problems between the genders?	Yes. Women are more likely to develop depression, anxiety, and post-traumatic stress disorder compared to men, while men are more likely to abuse alcohol. This is true in the general population as well as in disaster-exposed populations.
Does education of the public about the disasters help reduce emotional consequences of the disasters?	Education about common reactions to disasters is recommended. Explanations about what took place, in language that is accessible, and without lies and contradictions, can also be helpful. I am not familiar with research comparing the effectiveness of different forms of educational interventions about disasters. However, the field of risk communication may have conducted such studies.

Given the mental health impacts of Fukushima and the misinformation that appears to contribute, can public education help?	This is similar to the previous question. Common sense would indicate that misinformation is never a good idea. Individuals who work in the area of risk communication emphasize that *dialogue* is critical, not one-sided public education. Providing information without "listening" to questions and concerns from the public is inadequate. Dialogue also allows the communicators to fine tune their messages over time. Another reason to encourage dialogue is that, given the emotional consequences of nuclear power plant accidents, when people are fearful, they may not be able to hear the messages properly. We all engage in selective listening, but when we are afraid of something, we selectively hear "danger"' rather than "protection." For people who were told to evacuate (20 km zone), or told to limit their daily activities (20 to 30 km), dialogue is especially critical. Given the long-term fear about radiation exposure, and the lag time between exposure and cancer, setting up a dialogue is a long-term proposition. It is obviously also critical that messages be delivered and questions addressed by credible leaders whom the community trusts, and that they be targeted to multiple risk groups. I would also add that researchers have a moral obligation to present their findings to the public in language that is understandable and without dumbing down the data and behaving in a condescending manner. We also have an obligation to interact and answer questions. Indeed, I believe strongly that researchers should treat the people in their studies as "collaborators" and that these collaborators should be the first to learn about the findings, directly from the researchers, not from the mass media. To my knowledge, this did not happen on February 28, 2013 when the World Health Organization issued their latest report [WHO (2013). World Health Organization. *Health Risk Assessment from the Nuclear Accident After the 2011 Great East Japan Earthquake and Tsunami Based on a Preliminary Dose Estimation*, http://apps.who.int/iris/bitstream/10665/78218/1/9789241505130_eng.pdf (accessed August 16, 2013) (World Health Organization, Geneva].
What is the possibility that the evacuees from Fukushima may suffer health effects because they have been told or believe that such effects may occur?	Physical and mental health problems are high correlated, and epidemiologic evidence has shown clearly that prolonged anxiety and depression are associated with onset of many physical health problems later in life.

In your opinion, could more be done in the future to help the first responders such as the "liquidators" of Chernobyl to avoid anxiety, depressions, etc.?

There are many programs for developing resilience, and responders without prior training should receive some form of "stress inoculation" before going into a traumatic situation. There is research showing that first responders who have disaster training have lower rates of post-traumatic stress disorder than nontraditional responders. After 9/11, thousands of people from various occupations worked on the pile and other places where they experienced horrendous traumas. Several mental health reports showed significantly lower rates of post-traumatic stress disorder and depression during the decade following 9/11 among police and firefighters compared to untrained responders who came to help. Moreover, these problems were persistent over time rather than remitting.

Due to uncertainty, we cannot say there is no risk. So what can we say to explain "risk" without frightening the population?

This question is best addressed by experts in the field of risk communication. It is a very important issue. To answer this question personally, the comparator is critical. I would be reassured if I was told: "As a woman, the likelihood of developing cancer in your lifetime is 38 % (*i.e.*, one in three women develop cancer in their lifetimes). The extra risk, as someone who evacuated from the 20 km zone, is so small that it cannot be calculated exactly and will not be detectable in the future." If that were the message, and I trusted the source (!!!), I would feel quite reassured. The problem that arose after all three accidents is that the sources of information were viewed with distrust and suspicion, which only got worse with time. And conflicting messages were delivered by the Japanese government, the World Health Organization, and other international bodies, with little or no interaction with the affected populations.

Although Chernobyl and Fukushima accidents resulted in radiation exposures to the public, and Three Mile Island accident resulted in little such exposure, they all contributed to substantial mental stresses. Please explain why a nonpower plant accident such as Gioania accident of 1987 (in Brazil) also caused significant emotional stresses on the public?

Gioania was an event involving radiation exposure (a radioactive cesium teletherapy source was discarded and resulted in widespread contamination and death in a few instances), and radiation exposure tops the list of most dreaded exposures.

Can you highlight the importance of terminology (*e.g.*, "victim" versus "survivor") when talking to patients, the media, etc.?	The word "survivor" implies that one has actively and positively coped with an extreme stressor — hence the importance of the term "cancer survivor." The word "victim" implies that one has been overpowered by events. After Chernobyl, evacuees were referred to as victims. They did lose their homes and their sense of security about the future. But they have also gone on to live productive lives, raise healthy and happy children, and become integrated in their new communities. They are indeed survivors, not victims.
Is there any psychological effect (positive or negative) associated with enrolling a person in a long-term survival study? Can this increase the stress levels, or encourage a healthier lifestyle?	I don't know of any studies that examined whether being in a cohort study has beneficial effects compared to not being in a cohort study. But it is clear that there was a missed opportunity to address mental health concerns in the cohorts being followed for cancer onset after Chernobyl. There is a growing field called "mind-body medicine." The artificial separation of physical and mental health seems more and more counter-productive to improving the population's health.
Do you feel that local studies which showed a cognitive impairment were attempted to get increased funding from the international community or why do you feel that their results were so different?	In my mind, the main issue is that the controls were ill matched to the cases, and the raters who collected the data were not blind to exposure status. At the time these studies were conducted, the local understanding of epidemiologic methods was not consistent with the fundamental principles practiced in the United States and Europe. Plus, there was a societal bias that radiation exposure was the root of all health problems. The investigators were a product of their era and were as invested in this belief about radiation as was the general population and the press. In the cancer studies, transparent collaborations developed over time. Unfortunately, this did not happen with the mental health and cognitive impairment studies.
Please comment on the potential financial conflict-of-interest that Ukrainian researchers have — if they can show effects that can receive money from outside.	I think that this was a very real issue, and I'm not sure any of us would have behaved differently under the circumstances. After the Soviet Union broke apart, there was tremendous poverty and unemployment. Scientists worked as taxi drivers and mechanics in order to put food on the table. So yes, receiving funds from international sources was important for survival. Did some people take undue advantage? Of course, but this kind of thing happens in less obvious ways after many disasters.

Do you think it would help the mental state of the Japanese people if we held NCRP meetings and other radiation-related professional meetings inside the Fukushima exclusion zone?	We had three meetings sponsored by the Nippon Foundation and Fukushima Medical University and some of the speakers toured the reactors. Otherwise, we were not permitted inside the exclusion zone. I thought it was important that we were in Fukushima and eating local products because most Japanese citizens avoid buying products that come from Fukushima.
How does Bhopal accident compare to nuclear power plant accidents?	There were no epidemiologic mental health studies after Bhopal, but the papers written by a well known psychiatrist from India indicated that anxiety and depression were highly prevalent and persistent. Every accident is unique in the time and place of its occurrence. Each event is also unique in the secondary traumatic sequelae that they produce. Bhopal created horrific health issues, as did 9/11 for first responders. The secondary traumas from Chernobyl included evacuation, financial losses, and for some families, bereavement. Fukushima was part of a triple disaster and the list of the secondary traumas is considerably longer.
There are reports, although not rigorous epidemiological studies, of post-traumatic stress disorder (PTSD) in atomic-bomb survivors and Fukushima evacuees. **The atomic-bomb survivor studies indicate long-term psychosomatic and anxiety symptoms.** **So here are the questions:** **What is the evidence for a link between PTSD and cardiovascular disease?**	There is a growing literature on this topic that extends to hypertension, hyperlipidemia, and cardiovascular disease. I refer you to a recent review by Coughlin, S.S. [(2011). “Post-traumatic stress disorder and cardiovascular disease,” Open Cardiovasc. Med. J. **5**, 164–170].
Is there also evidence for increases in inflammatory markers in post-traumatic stress disorder (*e.g.*, cytokinetics and C-reactive protein)?	There is growing evidence from both epidemiologic and epigenetic studies, starting with Uddin, M., Aiello, A.E., Wildman, D.E., Koenen, K.C., Pawelec, G., de Los Santos, R., Goldmann, E. and Galea, S. [(2010). “Epigenetic and immune function profiles associated with posttraumatic stress disorder,” Proc. Natl. Acad. Sci. USA **107**(20), 9470–9475] and many papers since then.

MEDICAL SESSION

Questions for Dr. Dauer

For the lens of the eye dose estimation, what percent reduction would you recommend following use of drop-down shielding and leaded glasses?

See Thornton, R.H. and Dauer, L.T. (2010). ["Comparing strategies for IR eye protection in the interventional radiology suite," J. Vascular Intervent. Radiol. **21**(11), 1703–1707] for a detailed review of lens dose reduction factors that depend upon orientation and type of procedure.

According to NCRP Report No.168 [NCRP (2010). National Council on Radiation Protection and Measurements. *Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures*, NCRP Report No. 168, http://www.ncrppublications.org/index.cfm?fm=Product.Search&k=168&x=0&y=0 (accessed August 16, 2013) (National Council on Radiation Protection and Measurements, Bethesda, Maryland], the use of leaded glasses alone can provide a reduction factor of ~3 to 10, while suspended shields provide reductions of >25. In Thornton *et al*. above, suspended shields resulted in lens doses being routinely undetectable above background.

Do you have any advice on radiopharmaceutical pregnant workers?

Encourage workers to declare pregnancy. A woman who is an occupational radiation worker and has voluntarily informed her employer, in writing, of her pregnancy and the estimated conception [NRC (2013). U.S. Nuclear Regulatory Commission. "Standards for protection against radiation. Definitions," 10 CFR Part 20.1003 (U.S. Government Printing Office, Washington)]. This will enable the employer, in conjunction with the radiation safety officer and supervisors to evaluate historical dosimetry records and current work practices to ensure that the limits as noted in 10 CFR Part 20.1208 [NRC (2013). U.S. Nuclear Regulatory Commission. "Standards for protection against radiation. Dose equivalent to an embryo/fetus," 10 CFR Part 20.1208 (U.S. Government Printing Office, Washington)] can be met. In many cases, "as low as reasonably achievable" (ALARA) optimization techniques (*e.g.*, workload, distance, shielding) can be utilized as-needed in reducing dose to the embryo/fetus.

Can you show your radiochemical extremity/whole-body dose on a per megabecqueral (or per curie) of production? I would like to compare to my facility and this seems like the "fairest" way.	Good suggestion, we are pulling together 2 y worth of information and hope to publish such results within the next year.
How do you know your interventional radiology/interventional cardiology medical doctors are actually wearing their dosimeters for your data analysis? What percent of medical workers don't wear badges some or all of the time because of fear that they will exceed limits and have to stop working?	We audit for compliance. Our interventional radiology/interventional cardiology medical doctors actually wear their dosimeters when they are in their fluoro/angio suites. NCRP Report No.168 [NCRP (2010). National Council on Radiation Protection and Measurements. *Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures*, NCRP Report No. 168, http://www.ncrppublications.org/index.cfm?fm=Product.Search&k=168&x=0&y=0 (accessed August 16, 2013) (National Council on Radiation Protection and Measurements, Bethesda, Maryland] has excellent recommendations with regard to auditing compliance. At any point in time there are expected ranges of occupational dose for different job assignments. Doses to individuals outside of the expected dose ranges (either above OR below) should be investigated, as would sudden changes in an individual's dosimeter readings.

This is an issue with adequacy of dosimeter wearing by interventional vascular / interventional cardiology staff. If most actually receive 30 to 50 mSv y^{-1} (lens of the eye dose), would 20 mSv y^{-1} create an operational "problem" in medical practice?	For our practice, the average lens dose equivalent (LDE) was 11 mSv y^{-1}, the median LDE was 7 mSv y^{-1}. Therefore, most of our staff will likely be <20 mSv y^{-1}International Commission on Radiological Protection limit. However, it is true that about 25 % of our staff currently receive >20 mSv y^{-1} based on the current dosimetric methodology whereby we assign LDE based on collar badge readings [NCRP (2010). National Council on Radiation Protection and Measurements. *Radiation Dose Management for Fluoroscopically-Guided Interventional Medical Procedures*, NCRP Report No. 168, http://www.ncrppublications.org/index.cfm?fm=Product.Search&k=168&x=0&y=0 (accessed August 16, 2013) (National Council on Radiation Protection and Measurements, Bethesda, Maryland] for more information on LDE methods). Note that no "credit" has currently been incorporated for leaded glasses or other lens of the eye protection methods. This is something that needs to be evaluated further as well as additional optimization procedures [Thornton, R.H. and Dauer, L.T. (2010). "Comparing strategies for IR eye protection in the interventional radiology suite," J. Vascular Intervent. Radiol. **21**(11), 1703–1707] [Dauer, L.T., Thornton, R.H., Solomon, S.B. and St. Germain, J. (2010). "Unprotected operator eye lens doses in oncologic interventional radiology are clinically significant: estimation from patient kerma-area product data," J. Vascular Intervent. Radiol. **21**(12), 1859–1861].
What specific safety procedures have been implemented for ^{89}Zr?	Additional shielding for vials/syringes, reassessment of patient injection/resting area shielding adequacy, and as noted in the presentation an activity level of 5 mCi requiring patient instructions.

Questions for James Brink

What goes into the decision to do or not to do computed tomography?

The decision to do computed tomography (CT) should be based primarily on the medical need. For indicated studies, the potential benefits greatly outweigh the potential risks. Zondervan *et al.* (Zondervan, R.L., Hahn, P.F., Sadow, C.A., Liu, B. and Lee, S.I. (2013). "Body CT scanning in young adults: Examination indications, patient outcomes, and risk of radiation-induced cancer," Radiology **267**(2), 460–469) compared the mortality status among 22,000 CT scan patients between 18 and 35 y of age and found their mortality from their underlying medical conditions greatly exceeded their potential risk of fatal cancer induction from the ionizing radiation associated with their imaging procedures. Even for appropriate screening examinations such as CT colonography, Brenner and Georgsson (2005) concluded that the lifetime risk of colorectal cancer is 5 to 6 %, whereas the potential risk of radiation-induced cancer from CT colonography is 0.14 % for a 50 y old individual, the age at which conventional colonoscopy is recommended [Brenner, D.J. and Georgsson, M.A. (2005). "Mass screening with CT colonography: Should the radiation exposure be of concern?," Gastroenterology **129**(1), 328–337].Thus, the potential benefit greatly outweighs the risk for this imaging application.

Should advanced nurse practitioners or physician assistants be permitted to prescribe diagnostic exams that use ionizing radiation?

Nurse practitioners and physician assistants are licensed independent practitioners with the same ordering privileges for imaging examinations as physicians. In general, their training in the benefits and risks of diagnostic testing is sufficient to warrant these privileges.

What kind of patient dose controls exist for "virtual physical" centers, where people may get computed tomography "screenings" without their physician determining the exam is medically necessary? How does, or does not, this complement examinations in a medical setting, or are the scans having to be repeated?

The concern is that it seems patient dose is not a consideration if the patient desires a scan and has the ability to pay for it. I do not mean this to be offensive – the growth of "couture" computed tomography/magnetic resonance imaging centers has rapidly increased and is targeted at the consumer as a means of "preventive detection."

Whole-body computed tomography screening has been strongly renounced by several organizations including the American College of Radiology and the U.S. Food and Drug Administration. I am not aware that this practice is on the rise, and I believe that the public is generally aware of the risks of this practice.

WORKER EXPOSURES SESSION

Questions for James Neton

Why was there such a precipitous drop in ^{239}Pu dose around 1980?

Your observation is correct that there is a sharp drop in the reported 50th and 84th percentile urinary excretion of ^{239}Pu at the Hanford site starting in the early 1980s.On September 10, 1981, the site practice changed from recording 0.025 dpm per sample, to indicate a nondetectable value, to recording the exact result as measured. Because the data were no longer left-censored after this time, the fitted geometric mean and standard deviations for this and subsequent years were substantially reduced.

Given increasing awareness of the emotional consequences of radiation-related disasters, what are you doing to deal with this phenomenon?	Although the National Institute for Occupational Safety and Health (NIOSH) does not have a formal program in place to provide emotional counseling to claimants, we have established a number of avenues for workers and claimants to personally communicate the facts of their case and to voice their concerns and frustrations. As part of the NIOSH dose reconstruction (DR) process, each claimant is provided a single point of contact within NIOSH to deal with their case. In addition, prior to the initiation of a DR each claimant is interviewed to obtain any information that might be relevant to the case. Claimants are also provided the opportunity to voice their concerns during scheduled public comment sessions during routine meetings of the Advisory Board on Radiation and Worker Health. Finally, NIOSH participates in town hall meetings that are regularly scheduled by the U.S. Department of Labor to discuss newly added Special Exposure Cohort sites.
How has the increased number of people in the "Special Exposure Cohorts" impacted the compensation program?	The Energy Employees Occupational Illness Compensation Program (EEOICPA) made provisions for certain classes of employees to be added to what is called the Special Exposure Cohort (SEC). Under certain conditions, workers in the SEC class do not require dose reconstructions for any of 22 cancers. In general, the National Institute for Occupational Safety and Health finds that about 60 % of the cases in a designated class do not require dose reconstruction. Thus, the direct effect of adding a class to the SEC is a reduction in the number of dose reconstructions that must be completed for a site.

For those cases with lung cancer, was the additive or multiplicative effect of smoking or radon exposure considered?	The effect of smoking on the development of lung cancer is explicitly considered in the probability of causation calculation. Because there is uncertainty about the nature of the interaction between smoking and radiation exposure, the excess relative risk per sievert is adjusted using an uncertainty distribution with various weights given to the additive or multiplicative interaction. The adjustment for the interaction between radon exposure and smoking is also considered, but this adjustment, which relies on data collected from uranium miner studies, gives greater weight to the multiplicative interaction. A detailed discussion of these adjustments can be found in an article by Kocher *et al*. [Kocher, D.C., Apostoaei, A.I., Henshaw, R.W., Hoffman, F.O., Schubauer-Berigan, M.K., Stancescu, D.O., Thomas, B.A., Trabalka, J.R., Gilbert, E.S. and Land, C.E. (2008). “Interactive RadioEpidemiological Program (IREP): A web-based tool for estimating probability of causation/assigned share of radiogenic cancers,” Health Phys. **95**(1), 119–147].
How has the confounding factor of x rays for tuberculosis screening or to serve as a baseline to assess potential later bone damage been evaluated, and how does this influence epidemiological studies?	As mentioned in the presentation, the radiation exposure associated with diagnostic x rays is included in a worker’s dose reconstruction, as long as it was required as a condition of employment. Thus, if these types of x rays were required, they would be included in the worker’s total occupational exposure. While our division within the National Institute for Occupational Safety and Health (NIOSH) is not engaged in occupational epidemiologic studies, it would be important to consider exposure associated with these types of x rays in risk studies.
Can the reconstructed doses developed for compensation be credibly recalculated for use in epidemiological studies?	It is believed that the National Institute for Occupational Safety and Health (NIOSH) has collected sufficient data so that the doses reconstructed for compensation purposes could be recalculated for use in epidemiological studies. This would, of course, require additional funding that is beyond the scope of our current mission.
Are attorneys involved in compensation activities?	Yes, attorneys do represent some claimants within the Energy Employees Occupational Illness Compensation Program (EEOICPA).

Questions for Andre Bouville

What are the main factors that resulted in the maximum individual exposures being so different in the four largest nuclear accidents (Windscale, Three Mile Island, Chernobyl, and Fukushima)?

The four accidents were very different. The steam explosion at Chernobyl resulted in the loss of the containment and in a series of fires that had to be extinguished quickly. This is the reason of the very high radiation doses received during the first day of the accident. At Fukushima, the reason for the high exposures has not been officially provided (as far as I know), but it seems that air mainly contaminated with ^{131}I found its way to the reactor control room, where the workers were not equipped with respirators and had not taken potassium-iodide tablets. At Three Mile Island, the exposure situation was well managed, so that the maximum doses were relatively low. I am not familiar enough with the Windscale accident to explain why the maximum doses to the workers were also relatively low.

What fraction of the total Chernobyl liquidator workforce was actively monitored for radiation dose?

I do not think that there is any published information on this topic. According to unpublished information, ~15 to 20 % of the Chernobyl workforce was actively monitored by means of personal dosimeters. The other two methods that were used to determine dose at the time of exposure were:

1. the group assessment method (a personal dosimeter was worn by one member of a group of liquidators assigned to perform a particular task, and all members of the group were given the same dose); and
2. the calculation method (the dose to a group of liquidators was calculated in advance from the dose rate at the work location and the planned duration of work). Altogether, 48 % of the workers had a recorded dose [UNSCEAR (2010/2011). United Nations Scientific Committee on the Effects of Atomic Radiation. *Sources and Effects of Ionizing Radiation. UNSCEAR 2008 Report to the General Assembly, with scientific annexes* (United Nations Publications, New York].

Questions for Paul Blake

How are medical exposures tracked for the clinical use of x-rays/computed tomography/nuclear medicine procedures on soldiers for screening or injury?	This question falls outside of the speaker's expertise. For further information on this topic, interested parties should contact: Office of the Assistant Secretary of Defense for Public Affairs 1400 Defense Pentagon Washington, DC 20301-1400 (703) 571-3343 For further information see: http://www.defense.gov/
An atmosphere detonation participant was informed 30 y ago that his occupational dose was classified information. Are exposed individuals able to receive their personal doses from that time today?	Yes, this information is no longer classified. A U.S. military service member or civilian may request this information by: • calling this toll-free number: (800) 462-3683, or • emailing: ntpr@dtra.mil, or • writing: Defense Threat Reduction Agency J9-NTSN/NTPR 8725 John J. Kingman Road, MSC 6201 Fort Belvoir, VA 22060-6201 For further information see: http://www.dtra.mil/SpecialFocus/NTPR/NTPRHome.aspx

PUBLIC EXPOSURES SESSION

Questions for Harry Cullings

Given the low excess risk for radiation induced cancers and that all exposures seem to be additive, is there a role for research on the short term use of drugs before diagnostic radiation procedures? Or would the risk be too low to see an effect?

Is this a question about the possibility of using radioprotective drugs (*e.g.*, antioxidants, etc.)? As the questioner suggests, the dose for any one examination is typically so low that it is hard to imagine that any useful benefit would result if it were possible to do a cost-benefit analysis. Furthermore, virtually all research about radioprotectants is devoted to ameliorating tissue reaction and related systemic effects at much higher doses, not at reducing the sorts of events such as mutation that would be associated with induction of cancer or other late stochastic effects.

Atomic-bomb survivors were exposed to combined effects of radiation, thermal burns, physical blast injuries, etc., yet all cancer excesses are attributed only to radiation. Have the effects of these nonradiation stresses been studied in the past? Are any studies planned?

Acknowledging the difficulty of differentiating influences of radiation blast and heat on early health effects, can this be done for cancer?

To my knowledge, thermal and blast injuries have never been studied as an effect modifier or as risk factors in their own right, for increased late mortality or incidence of cancer. Actually, the hypothesis that has been at issue has been a different one: that persons who survived the combined injury long enough to be included in the Atomic Bomb Casualty Commission (ABCC) cohorts tended to be healthier overall than those who did not, and that this conferred a "healthy survivor" effect. This hypothesis was advocated by Alice Stewart and others, and efforts have been made to evaluate the resulting potential selection bias [Pierce, D.A., Vaeth, M. and Shimizu, Y. (2007). "Selection bias in cancer risk estimation from A-bomb survivors," Radiat. Res.**167**(6), 735–741]. Anyway, the idea of these injuries as risk factors or effect modifiers for late stochastic effects does raise an interesting research question.

The Otake and Schull studies used post-conception weeks for timing pregnancy — not gestational weeks.

Yes, Otake and Schull used the elapsed time from the presumed date of fertilization and not the time since the last menstrual period. The latter is often used to define "gestational age" in human obstetrics, although they refer to "gestational age" in the same context in which they define their time variable as elapsed time since fertilization [Otake, M. and Schull, W.J. (1998). "Radiation-related brain damage and growth retardation among the prenatally exposed atomic bomb survivors," Intl. J. Radiat. Biol. **74**(2), 159–171].

Have there been any excess solid cancers or leukemia for doses that did not exceed about 0.1 to 0.2 Gy?	When a linear model is fitted to the incidence data for solid cancer over a wider dose range, there are about 159 fitted excess cases among survivors with colon doses <0.2 Gy, with about 84 fitted excess cases among those with colon doses <0.1 Gy [Table 9 of Preston, D.L., Ron, E., Tokuoka, S., Funamoto, S., Nishi, N., Soda, M., Mabuchi, K. and Kodama, K. (2007). "Solid cancer incidence in atomic bomb survivors: 1958-1998," Radiat. Res. **168**(1), 1–64]. Of course these numbers are smaller if a linear-quadratic model is used, but they are not zero. On the other hand, if one uses only a limited range of doses from zero to some specified maximum, 0.15 Gy is about the lowest such maximum for which a linear dose response is statistically significant (Preston *et al.*, 2007).
How does the loss of life expectancy scale with dose for exposure ages <5 y?	For a linear dose-response model, the unconditional probability of dying in any subsequent, short interval of time increases linearly with dose in a linear excess relative risk model. However, the number of days of life lost depends in a more complicated way on the probability of dying in a given interval conditional on surviving until the beginning of the interval, for which survival is affected by the increased risk of dying in previous intervals due to the radiation; hence, there is not necessarily a linear dependence. Cologne, J.B. and Preston, D.L. [(2000). "Longevity of atomic-bomb survivors," Lancet **356**(9226), 303–307], found, for example, that in considering all-cause mortality, the median life expectancy declined more rapidly at high doses.

Please say more about sequencing in the genetics studies.

Radiation Effects Research Foundation (RERF) studies focus on detecting radiation-induced germline mutations (*i.e.*, a mutation in a child that is not present in either parent) which arose because one of the parental gametes, sperm or oocyte, was mutated by radiation exposure of the parent's gonads prior to the child's conception. Presently, RERF is using comparative genomic hybridization with arrays of high-density probes located at unique sites spaced at intervals ~1 to 3 kb (1,000 to 3,000 nucleotides) along the genome, which in principle allows detection of mutations consisting of insertion or deletion of segments of the genome a few times this size or larger, by detecting the associated change in copy number for the segment in question. The use of sequencing, in contrast, in principle allows detection of mutations down to the level of changes in single nucleotides (single nucleotide variants). However, candidate mutations detected by comparing parents' and child's sequences must be confirmed by a more laborious, targeted sequencing of an associated segment of DNA with the Sanger method. Given the extremely broad spectrum of theoretically detectable mutations, the error rates in the sequencing, and potential artifacts such as somatic mutations, it must be determined whether the number of false positive results can be controlled to levels low enough to be practicable for all candidate results to be confirmed by Sanger sequencing.

Is telomere shortening, which is a possible sign of life shortening, seen in F_3 descendants?

Probably the questioner means F_2, as F_3 would be the survivors' children's children's children. So far, only the survivor's children have been studied. No cohort of the children's children (F_2) has yet been formed. Telomere shortening has been studied at the Radiation Effects Research Foundation as a marker in immune cell populations [Ohara, T., Koyama, K., Kusunoki, Y., Hayashi, T., Tsuyama, N., Kubo, Y. and Kyoizumi, S. (2002). "Memory functions and death proneness in three CD4+CD45RO+ human T cell subsets," J. Immunol. **169**(1), 39–48], but to my knowledge have not been studied as an indicator of life shortening.

Why is the loss of life expectancy per radiation-associated case preferred to loss of life expectancy per exposed person? If radiation increases the hazard for every exposed person, isn't the second quantity more informative?

Furukawa *et al.* [Furukawa, K., Cologne, J.B., Shimizu, Y. and Ross, N.P. (2009). "Predicting future excess events in risk assessment," Risk Anal. **29**(6), 885–899] estimated loss of life expectancy as the difference in life expectancy between those in an exposed group and those in an unexposed group, where life expectancy was calculated as the integral over time of the estimated survival function, beginning at age at exposure. They did not express the loss as a loss per radiation-associated case or per exposed person. Methods are given in detail in the appendix of Furukawa *et al.* (2009).

Questions for Bruce Napier

You indicated that the dose effects from internal sources and external sources are commensurate. Is this true for specific cancer types?

It does appear from the preliminary data that the International Commission on Radiological Protection (ICRP) paradigm of equivalence of internal and external doses is correct. From the Chernobyl thyroid studies, with respect to thyroid cancer, there is pretty solid evidence that the magnitude of risk following exposure to radioiodines in childhood/adolescence is consistent with risk from exposure to external radiation in childhood. The risk from radioiodine exposure in adulthood has not yet been established. From the Techa River studies of solid cancers, portions of the cohort have large external doses in addition to their internal doses, and these allow us to investigate whether there are differences in effect; the results so far suggest that they are similar. It is not possible to say much about specific cancer types with the Techa River cohort because the low number of cases does not allow much specification before statistical significance is lost. In addition, in the Mayak worker studies (mentioned earlier by Andre Bouville), many workers have very large lung doses from inhaled plutonium. A recent paper by Ethel Gilbert and colleagues [Gilbert, E.S., Sokolnikov, M.E., Preston, D.L., Schonfeld, S.J., Schadilov, A.E., Vasilenko, E.K. and Koshurnikova, N.A. (2013). “Lung cancer risks from plutonium: an updated analysis of data from the Mayak worker cohort,” Radiat. Res.179(3), 332–342] presents an interesting comparison with the Radiation Effects Research Foundation’s Life Span Study (LSS), in which they compared the risks of lung cancer on the basis of effective dose by multiplying the Mayak absorbed lung dose by a radiation weighting factor. If the Mayak estimate is expressed in terms of sievert with a weighting factor of 20 as recommended by the ICRP, it becomes very similar to the low linear-energy transfer (LSS)-based estimates.

What other toxic chemicals were discharged into the Techa River? Has this been accounted for? Have other cancer causing agents been accounted for in the study?

How are potentially confounding chemical exposures being addressed for the Techa River cohorts?

As normal for the time, chemical wastes were also routinely discharged into the local surface water bodies. The Joint Coordinating Committee for Radiation Effects Research projects have not focused on those chemical releases. Although it might seem that the chemical releases could have been huge (given the radiation releases), this is not likely. If the chemicals were having a confounding impact on the health studies, we might expect to see chemical-specific effects (such as certain organ-specific cancers) or impacts that differ from those expected from radiation exposure. Neither of these has been seen. We might also expect that any putative effects would not have a direct relationship with the combination of internal and external doses (which vary dramatically downstream along the river between villages with wells and villages that obtained water from the river); the observed impacts seem to be very linear with the levels of estimated dose.

The Japanese have been warned not to drink the milk from cows around [near] Fukushima or eat the food grown in the area. Can we compare their potential internal exposure to those in Muslyumovo?

The internal doses from Fukushima are believed to be very low; as mentioned by Dr. Yamashita, measurements of Fukushima Prefecture residents indicates internal doses <1 mSv from iodine and cesium. The doses at Muslyumovo are much higher; internal doses primarily from strontium in bone could be 1,000 times greater than at Fukushima.

Questions for Dan Stram

For U.S. nuclear power plants, the maximum offsite doses are extremely small. Isn't it obvious that any observation of a statistically significant relative risk would be an artificial finding? Why is this study being done at all?

In my opinion public concerns about the U.S. Nuclear Regulatory Commission relying on a single epidemiological study 20 y old to defend U.S. nuclear power plant safety are the reasons behind this study. I agree that nominally statistically significant results need to be interpreted carefully because of inherent problems related to multiple statistical testing (*i.e.*, testing of many different diseases in relation to many different plants). These concerns can be mitigated somewhat by careful accounting of the number of tests being performed, and ensuring that the most important hypotheses (primary hypotheses) being tested are not confused with subset analyses.

You mentioned there is no scientific justification for the National Academy of Sciences' study on cancer risks near nuclear power plants, but the justification for the study is based on public concerns. What is the estimated cost of the pilot study? Would the public have trust in the conclusions of such a study?

I think I said that this study is not designed to tell us new information about the effects of radiation exposure per say, because the doses are too small to be studied epidemiologically and are swamped by other sources of radiation (*e.g.*, environmental and medical). The study could rule out certain high risks that while not scientifically likely, could be of concern to the public.

In my opinion the study will be believed by most people if it is perceived to have been designed and analyzed in an unbiased way by scientists, doctors and epidemiologists who are perceived to be without vested interest in the outcome of the research.

Regarding costs I would have to deter to the Nuclear and Radiation Studies Board or the U.S. Nuclear Regulatory Commission. However, news media reports have put the cost of the pilot study in the two million dollar range.

If reported public exposures are even qualitatively accurate, medical exposures will swamp dose. How will this source of confounding be considered? Note that such exposures will be highly dependent on factors such as income.

Socioeconomic variables available at census tract level are to be relied upon to provide control for confounding of this type. There are many uncertainties as to how relevant this will be, especially for mobile populations.

Questions for Maureen Hatch

How important was iodine deficiency in the Chernobyl population for the risk of thyroid cancer from ^{131}I?

Iodine deficiency (ID), which can increase uptake of radioiodines and may influence progression of thyroid disease, is prevalent in Chernobyl-affected areas. The interaction between ID and radiation exposure from Chernobyl fallout has been examined in only a few studies. Most suggest a joint effect [Shakhtarin, V.V., Tsyb, A.F., Stepanenko, V.F., Orlov, M.Y., Kopecky, K.J. and Davis, S. (2003). “Iodine deficiency, radiation dose, and the risk of thyroid cancer among children and adolescents in the Bryansk region of Russia following the Chernobyl power station accident,” Intl. J. Epidemiol. **32**(4), 584–591] [Cardis, E., Kesminiene, A., Ivanov, V., Malakhova, I., Shibata, Y., Khrouch, V., Drozdovitch, V., Maceika, E., Zvonova, I., Vlassov, O., Bouville, A., Goulko, G., Hoshi, M., Abrosimov, A., Anoshko, J., Astakhova, L., Chekin, S., Demidchik, E., Galanti, R., Ito, M., Korobova, E., Lushnikov, E., Maksioutov, M., Masyakin, V., Nerovnia, A., Parshin, V., Parshkov, E., Piliptsevich, N., Pinchera, A., Polyakov, S., Shabeka, N., Suonio, E., Tenet, V., Tsyb, A., Yamashita, S. and Williams, D. (2005). “Risk of thyroid cancer after exposure to ^{131}I in childhood,” J. Natl. Cancer Inst. **97**(10), 724–732] [Zablotska, L.B., Ron, E., Rozhko, A.V., Hatch, M., Polyanskaya, O.N., Brenner, A.V., Lubin, J., Romanov, G.N., McConnell, R.J., O'Kane, P., Evseenko, V.V., Drozdovitch, V.V., Luckyanov, N., Minenko, V.F., Bouville, A. and Masyakin, V.B. (2011). “Thyroid cancer risk in Belarus among children and adolescents exposed to radioiodine after the Chornobyl accident Br. J. Cancer **104**(1), 181–187] although a cohort study in Ukraine found no significant evidence,” that low levels of stable iodine increased the risk from radiation [Tronko, M.D., Howe, G.R., Bogdanova, T.I., Bouville, A.C., Epstein, O.V., Brill, A.B., Likhtarev, I.A., Fink, D.J., Markov, V.V., Greenebaum, E., Olijnyk, V.A., Masnyk, I.J., Shpak, V.M., McConnell, R.J., Tereshchenko, V.P., Robbins, J., Zvinchuk, O.V., Zablotska, L.B., Hatch, M., Luckyanov, N.K., Ron, E., Thomas, T.L., Voillequé, P.G. and Beebe, G.W. (2006). “A cohort study of thyroid cancer and other thyroid diseases after the Chornobyl accident: thyroid cancer in Ukraine detected during first screening,” J. Natl. Cancer Inst. **98**(13), 897–903]. It is important to resolve the issue since iodine prophylaxsis could potentially play a role in minimizing adverse effects from radioiodine exposure in future nuclear accidents.

What do results from the Chernobyl thyroid epidemiology studies tell us about dose and dose-rate effectiveness factor (*i.e.*, through comparisons of the dose responses from ^{131}I in Chernobyl to outcomes for the acute exposures in the Life Span Study)?

The evidence of a linear dose response for ^{131}I exposure at low-dose levels and the comparability of the excess relative risks from ^{131}I and atomic-bomb exposure seem to suggest a dose and dose-rate effectiveness factor value of one; however, the data are consistent with a range of values — lower or higher than one — due to statistical and other uncertainties.

Do you have data from Chernobyl or elsewhere that pertains to radiogenic thyroid cancer risks for ages >40 y?

The question of thyroid cancer risk following exposure in adulthood is of increasing interest, both among radiation scientists and those involved in radiation protection. Although the data are limited, there is evidence from recent studies of cancer incidence among nuclear workers [Muirhead, C.R., O'Hagan, J.A., Haylock, R.G., Phillipson, M.A., Willcock, T., Berridge, G.L. and Zhang, W. (2009). "Mortality and cancer incidence following occupational radiation exposure: Third analysis of the National Registry for Radiation Workers," Br. J. Cancer **100**(1), 206–212] and Chernobyl cleanup workers [Kesminiene, A., Evrard, A.S., Ivanov, V.K., Malakhova, I.V., Kurtinaitise, J., Stengrevics, A., Tekkel, M., Chekin, S., Drozdovitch, V., Gavrilin, Y., Golovanov, I., Kryuchkov, V.P., Maceika, E., Mirkhaidarov, A.K., Polyakov, S., Tenet, V., Tukov, A.R., Byrnes, G. and Cardis, E. (2012). "Risk of thyroid cancer among Chernobyl liquidators," Radiat. Res. **178**(5), 425–436] of a raised risk of thyroid cancer from exposure as an adult. A new study on this topic in a cohort that includes female as well as male liquidators is currently in planning by the National Cancer Institute and collaborators at the Research Center for Radiation Medicine in Ukraine.

Is there any ongoing follow-up on potential thyroid cancer from above-ground weapons testing in Nevada during the 1950s?

A prospective cohort of ~2,500 school children exposed to radioactive iodine from Nevada Test Site fallout has been followed for thyroid disease since 1965. In 2006, a dose-related increase in risk of thyroid neoplasms and autoimmune thyroiditis was reported, but there were too few malignant cases to estimate risk of thyroid cancer [Lyon, J.L., Alder, S.C., Stone, M.B., Scholl, A., Reading, J.C., Holubkov, R., Sheng, X., White, G.L., Jr., Hegmann, K.T., Anspaugh, L., Hoffman, F.O., Simon, S.L., Thomas, B., Carroll, R. and Meikle, A.W. (2006). "Thyroid disease associated with exposure to the Nevada nuclear weapons test site radiation: A reevaluation based on corrected dosimetry and examination data," Epidemiology **17**(6), 604–614]. The most recent paper based on this cohort [Stone, M.B., Stanford, J.B., Lyon, J.L., VanDerslice, J.A. and Alder, S.C. (2013). "Childhood thyroid radioiodine exposure and subsequent infertility in the intermountain fallout cohort," Environ. Health Persp. **121**(1), 79–84] links childhood exposure to radioiodines with subsequent infertility.

Question for John Boice

Risk communication is not the only problem. A more important problem is the risk model [linear nonthreshold (LNT) model]. LNT model cannot explain the deviation from linearity in the atomic-bomb survivor data [Ozasa, K., Shimizu, Y., Suyama, A., Kasagi, F., Soda, M., Grant, E.J., Sakata, R., Sugiyama, H. and Kodama, K. (2012). "Studies of the mortality of atomic bomb survivors, Report 14, 1950–2003: An overview of cancer and noncancer diseases," Radiat. Res. 177(3), 229–243] arising from the less than expected cancers for doses of 0.3 to 0.7 Gy. Since the atomic-bomb survivor data is the best (gold standard) data available. The LNT model should not be used any longer for evaluating populations for low level exposures because of the immediate emotional harm being caused. The unsuitability of LNT model should be publicized to reduce the fear of low-dose radiation. Can you lead such an effort, effectively reversing our course in the use of LNT model?

NCRP is directing research that will provide much needed scientific information regarding the LNT hypothesis and its application in radiation protection. The one unanswered question of critical importance in radiation epidemiology and protection deals with the health effects following radiation exposures that are received gradually and not all at once. While the study of Japanese atomic-bomb survivors is the single most important study to date, it is severely limited because the exposure was received in less than a second to a 1945 Japanese population living in a war-torn country. The ongoing One Million U.S. Radiation Worker and Veteran Study has widespread national partnership with the U.S. Department of Energy (DOE), U.S. Nuclear Regulatory Commission (NRC), National Aeronautics and Space Administration (NASA), U.S. Environmental Protection Agency (EPA), National Cancer Institute (NCI), U.S. Department of Defense (DOD), and U.S. Department of Veterans Affairs (VA) in addition to universities and other organizations throughout the country [Boice, J.D., Jr. (2012). "A study of one million U.S. radiation workers and veterans a new NCRP initiative (DOE Grant Awarded September 2012)," http://www.ncrponline.org/PDFs/BOICE-HPnews/Nov-2012_Million_Worker.pdf (accessed August 16, 2013). Health Phys. News **XL**(11), 7–10] Further, epidemiology does not have the ability to detect unequivocally health effects at low doses less than ~100 to 150 mSv or so. Thus to more accurately estimate and assess radiation effects at low doses it is essential that we integrate basic science with epidemiology. There is a tremendous amount of biological data at low doses from experimental studies that might be combined with human studies. Accordingly, NCRP has an ongoing scientific committee (SC 1-21) that is addressing the possible marriage of epidemiology with basic science to improve radiation risk estimation at low doses [NCRP (2013). National Council on Radiation Protection and Measurements. *SC 1-21: Health Effects of Low Doses of Radiation: Integrating Basic Science and Epidemiology*, http://www.ncrponline.org/Current_Prog/SC_1-21.html (accessed August 16, 2013) (National Council on Radiation Protection and Measurements, Bethesda, Maryland]. The validity and applicability of the LNT model to radiation protection is of critical importance to society as we deal with assessing the actual and potential health effects from radiological incidents such as Fukushima, from the ever-increasing uses of radiation in medicine from imaging with computed tomography and radionuclides, from possible terrorist events, in environmental cleanup circumstances, in the workplace and for so many more as yet unimagined or unanticipated uses of radiation in the future (*e.g.*, nanotechnology).