SUMMARY
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RADIATION EMERGENCIES
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***Please note:** Data and analysis discussed in these presentations were current when presented. Data collection and analysis are ongoing in many cases, therefore updates may be forthcoming elsewhere on this website, through publications such as CDC's Morbidity and Mortality Weekly Report or other venues. Presentations themselves will not be updated. Please bear this in mind when citing data from these presentations*

Our comments today are going to be focused primarily on terrorism issues: nuclear and radiological terrorism. Unfortunately, terrorism is a real threat in the United States today, and radiation can certainly be used as an agent to harm people and to terrorize communities and cities.

Here are five possible scenarios for radiation terrorism:

- Nuclear power-plant incident: This could be a direct attack by a terrorist group on a nuclear power plant or sabotage that happens within the plant. Either event could release radioactivity into the environment and expose people both onsite at the plant and offsite.
- Hidden source of radiation: This might be a source stolen from an industrial facility, a cobalt source for example, or perhaps a cesium source from a medical facility. It could be hidden somewhere, such as in a public park, and expose people without their knowledge. Possibly only a handful of people would be acutely exposed, but they could receive lethal radiation doses.
- Dirty bomb: This is a conventional bomb laced with a radioactive substance such as cobalt-60. In this scenario, there could certainly be a lot of devastation. People could be killed as with any bomb blast, but in addition, the victims and people near the blast site, such as first responders, would be irradiated. We generally would not expect lethal doses of radiation from such a scenario, but there could nevertheless be a significant public health issue of widespread radioactive contamination and radiation exposures.
- Improvised nuclear device (IND): This is a makeshift bomb that could be assembled by a terrorist group with access to expertise in nuclear weapon design as well as to special

nuclear material. If it were successfully detonated, the result would be similar to the nuclear explosions that occurred at Hiroshima and Nagasaki.

- Nuclear weapon: Of course, there still exist nuclear weapons in the world today, and we cannot rule out the use of one of those in a terrorist attack.

A few years ago, the Chair of the Armed Forces Research and Development Subcommittee in the House, Chairman Dan Burton, demonstrated a mock-up of a nuclear device that he said could have the yield of about one-tenth of the Hiroshima bomb and would fit inside a suitcase. He was referring to an actual nuclear detonation. While a nuclear detonation may be a highly unlikely scenario, the consequences would be so devastating that it is simply prudent for us to take the possibility into consideration in our terrorism response planning.

I would also like to provide some basic definitions pertaining to radiation that will be used frequently today:

- Radiation is energy transported in the form of particles or waves.
- When we speak of radiation in the context of a terrorist attack, we are referring to nuclear or ionizing radiation. In that context, it is penetrating radiation, not radiation like microwaves or from a cell-phone tower, for example. We refer to the latter as non-ionizing radiation. That type of radiation is outside the context of today's topic.
- Nuclear or ionizing radiation, which is what we are talking about today, is radiation that is sufficiently energetic to disrupt molecular structures and produce ionization of atoms and molecules.
- There are different types of ionizing radiation classified according to their penetration ability.
    - The most common types that we would deal with in the scenarios described above are alpha, beta, gamma, and neutrons.
    - Alpha radiation is radiation that is not at all penetrating. It can be stopped by a layer of dead skin or a sheet of paper, for example.
    - Beta particles might be stopped by a layer of clothing if they were low-energy betas. Higher-energy betas might require a half an inch or so of plastic in order to stop them.
    - Gamma rays and neutrons, on the other hand, are very penetrating types of radiation and normally require a fraction of an inch of lead or several feet of concrete to stop them, especially for the neutrons, which would normally require several feet of concrete. We would not be concerned with neutrons in most of the scenarios above. They would be produced in a nuclear fission event as from an improvised nuclear device or a nuclear weapon.

- Radiation has an advantage over chemical and biological agents in terms of the ability to readily detect it at very low levels. We can generally easily detect the various types of radiation (alpha, beta, gamma, and neutron radiation) with appropriate instruments.

- There are cheap, very portable instruments available that can measure low levels of radiation, which are easy to use with proper training. For example, there are alpha survey meters or beta and gamma survey meters, such as Geiger counters.
- Distinction between radiation and radioactive material:

    - Radiation is the energy that is transported in the form of particles or waves: alpha, beta, or gamma radiation, for example.
    - Radioactive material contains atoms that emit radiation spontaneously. Examples include: cesium-137, iodine-131, cobalt-60, phosphorous-32, carbon-14, and tritium.

- Distinction between exposure versus contamination:
    - *Exposure* is irradiation of the body. A beam of ionizing radiation energy can be absorbed by the body. That radiation-absorbed dose is measured in units such as Gray(Gy) or rad.
    - *Contamination* is radioactive material that is on the victim or patient (external contamination) or within the victim (internal contamination).
    - Radioactive contamination generally is easily removable. For example, 80% to 90% of it is often removed just by removing the clothing from the victim or the patient. Any contamination that is left on the skin is generally easily washed off, and Dr. Fong will discuss this procedure in more detail.

In conclusion, as you prepare in your emergency training and exercises for a possibility of a nuclear or radiological event, it is very important that you consult with radiation experts. Radiation safety officers, health physicists, and medical physicists are the three primary professional groups. Larger institutions, including hospitals, generally have a health physicist or medical physicist on staff.

If you work in an area where radiation experts are not readily available, please consult the Web site of the Conference of Radiation Control Program Directors www.crcpd.org, a non-profit organization of professionals who deal with radiation protection. They are represented in virtually every state and can help you locate radiation experts who can advise on such matters as documenting the presence of radioactivity, radiation doses, collecting biological and other samples, decontamination procedures, disposing of radioactive waste, and a host of issues where you really need a radiation expert's assistance.

Fun Fong, M. D., FACEP
Staff Emergency Physician
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I will talk about injuries that are associated with radiation casualties, clinical staffing issues and how to work with staff to prepare your emergency department to receive casualties, and how we

triage such casualties. I'll also talk briefly about acute radiation syndrome and about skin effects and decontamination as well.

INJURIES ASSOCIATED WITH RADIOLOGICAL CASUALTIES

- Classical acute radiation syndrome, that is, systemic effects from radiation exposure
- Localized radiation injuries
- Musculocutaneous radiation syndromes (skin and localized radiation injury).
- Internal or external radioactive contamination.
- Combined injuries, that is, radiation injury combined with some type of conventional injury, either trauma or burns
- Fetal effects of radiation exposure or contamination
- Long-term effects of radiation exposure or contamination
- Psychological components of a radiation event (post-traumatic stress disorder among victims and health care providers; survivor guilt)

CLINICAL STAFFING ISSUES

- In considering clinical staff in the context of a radiation emergency, think about the principles of minimizing radiation exposure. These would be time, distance, and shielding.
- Time and distance are pretty intuitive. Minimize the amount of time that we work around the radiation. Maximize the distance that we are working in from the presence of radiation.
- Shielding is not as important an issue for health-care workers caring for victims of radiation events.
    - Shielding in health-care settings for radiological procedures is primarily for x-rays, whereas the typical radiation that encountered in a radiation event is frequently gamma radiation, for which x-ray shielding is not useful.
    - The amounts of contamination that health-care workers are likely to be exposed to are typically quite low.
    - Rarely has any health-care provider been exposed to more than 50 millirem for any particular incident, and in the worst-case scenario, we'll talk about medical providers in the case of the Chernobyl disaster.

Personal Protective Equipment

- Handle radiation victims the same way you would handle a trauma response, and use standard barrier protection, including some type of impermeable trauma apron, booties, and gloves.
    - Use a mask as protection from fluids.
    - If there is concern about airborne particulates, use an N-95 or greater respirator.
    - Use a surgical hair net or cap if there is concern about fluids or particulates on the hair.

Decontamination

- Victims can be decontaminated either outdoors or indoors.
- Decontamination indoors allows being able to deal with medical issues much more effectively than outdoors.
- Which approach to use will need to be a judgment call by the lead physician providing the response.

Contamination Control

- Health-care workers deal with contamination in the normal course of clinical work but not as strictly as is necessary in a radiation setting.
- The basic approach is to keep contaminated materials contained in an area and to keep other areas free from contamination.
- This requires setting up control lines, delineating areas for working with contaminated patients and contamination, and identifying areas that are to be kept free of contamination.
- Set up checkpoints with people with survey meters to check to make sure that no contamination gets into an area that is meant to be a clean area and to prevent contamination from spreading within the hospital. That would be disastrous for a hospital, where other critical procedures and operations are ongoing. To have critical functions hindered or stopped by contamination issues could in itself be life-threatening.
- A radiation response area should include:
    - An area for caring for the contaminated patient
    - Buffer area or zone for checking people to be sure they're clean before going in and to be sure contaminated material is not going out of the area
    - Clean area (or "cold" area) for personal protective equipment such as boots, masks, gloves, gown, and booties. Stock this area generously as there will be people continuously going in and out who will need protective garments.

Pregnant Workers

- There is a radiation exposure limit for pregnant women of half a rad. That would be five mGy. That is a Nuclear Regulatory Commission (NRC) limit.
- Pregnant workers can work in a radiation response area if radiation exposure is limited to 5 mGy; however, it is probably easiest to simply reassign pregnant health-care workers to an area that does not deal with contamination unless they have strong objections.
- There is a prenatal radiation exposure fact sheet on the CDC Web site at www.bt.cdc.gov/radiation/prenatalphysician.asp.

Dealing with Staff Stress

Preplanning

- Establish an information center to inform relatives of victims and to let staff know about their families.
- Train staff on radiation basics, including radiation emergency drills

Post Event

- Debrief personal immediately after an event. It's important to know what went right and what went wrong, sources of stressors for personnel during the event, and to identify people who may need counseling afterwards.
- Offer counseling both for responders and for victims. Responders will need to have counseling depending on the immediate stresses of the event and its long-term ramifications, and victims may need long-term counseling as to exactly what types of things to expect after their exposure.
- In the 1986 Chernobyl accident, the worst-case scenario to date, the maximum amount of radiation that any medical provider received was less than 10 mGy of radiation, or approximately one RAD in common units. One rad is approximately equivalent to that received in a pelvic CT scan. .

MEDICAL MANAGEMENT

- Never delay critical care because a patient is contaminated. A patient will not incur significantly more morbidity or mortality because they are contaminated or because attention to their radiation exposure or contamination is delayed; however, delaying care for conventional medical issues, such as trauma, could cause significant morbidity and mortality.
- It's very important to make sure that the patient is medically stable before proceeding with tackling the issue of the radiological contamination or other radiation issues.

Immediate Medical Management

Standard medical triage is the first priority. Radiation exposure and contamination are secondary.

- Radiation Triage would attempt to quantitate: (Is this the right way to state this?)
    - Acute radiation syndrome (ARS)
    - combined injury

- Perform initial stabilization and treatment according to the usual ACLS/ATLS type protocols immediately after receiving the patient.
- Assess psychological effects. Integrate the psychological team into the medical team once initial stabilization is complete rather than making their intervention a separate step.
- Keep good records on each patient noting exposure or contamination levels on some type of body diagram.
- Record keeping/ Dose assessment

    - Try to assess the dose of radiation the patient has received.
    - Tell the patient that you are working on the assessment, but that this can take from a few hours to several days.
- Patient management protocol consists of assessing the following:
    - Assess and treat injuries.
    - Assess signs and symptoms.
    - Take patient history to include patient's proximity to the radioactive blast or release.
    - Perform a survey of the patient's contamination levels.
    - History and contamination levels together enable determination of degree of exposure and possible systemic exposure.

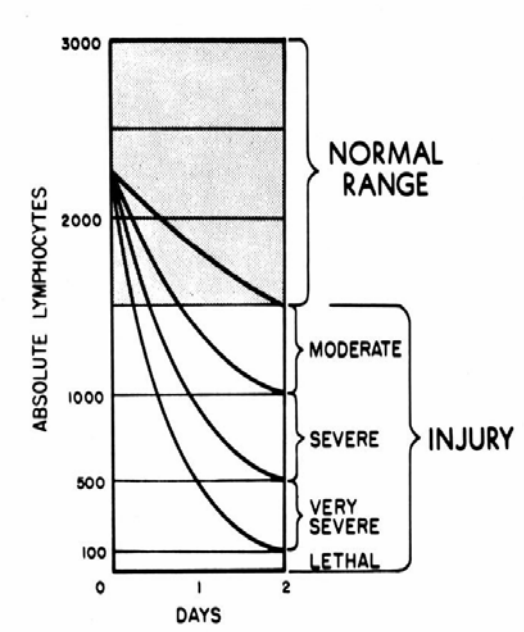
Prenatal Radiation Exposure

- The human embryo and fetus are highly sensitive to ionizing radiation.
- At higher doses, effects depend on dose and stage of gestation.
- Pregnant patients should receive special dose assessments and counseling.
- Information on prenatal radiation exposure: www.bt.cdc.gov/radiation/prenatalphysician.asp

ACUTE RADIATION SYNDROME (ARS)

- The following exposure factors are characteristic of ARS:
    - Large dose of radiation
    - Penetrating radiation (able to reach internal organs)
    - Most of body exposed
    - Acute timeframe (dose delivered in a short period of time)
- The threshold for ARS is a dose of 25 rad at which some hematopoietic effects occur, notably depression of blood elements within the bone marrow.
- At levels above the threshold for bone marrow depression effects in the gastrointestinal, pulmonary, and cardiac systems occur, and at the highest levels, the central nervous system is affected.
- Onset to nausea, vomiting, and diarrhea
    - Those with significant exposure will experience these symptoms within a few hours of exposure.
    - The more severe the exposure, the more rapid the onset of these symptoms.
    - If none of these symptoms occur for approximately three hours, there has been no significant exposure.
- Biodosimetry Assessment Tool, the BAT, is a software tool useful to help quantitate an initial estimate of exposure. (Available at the Armed Forces Radiobiological Research Institute www.afrri.usuhs.mil)
- Note that all of the signs and symptoms of acute radiation exposure can be caused by stress or other illnesses.

- Confirm ARS using Andrews Lymphocyte Nomogram, which uses serial CBCs and graphing of changes in the absolute lymphocyte count over a 48-hour period (see below).
    - Confirms suspected radiation exposure
    - Determines significant hematological involvement
    - Perform serial CBCs every 3 – 4 hours
    - If patient appears ill, do CBCs more quickly; if appears well, may perform less often



Andrews Lymphocyte Nomogram

- Phases of Acute Radiation Syndrome
    - Prodromal phase
    - Latent phase
    - Manifest illness phase
    - Recovery
- If emergency surgery is necessary, perform surgery before hematopoietic depression occurs, usually within 24-48 hours of exposure.
- Other surgery, such as reconstructive and restorative, can be performed after hematopoietic recovery, normally two to three months.

SKIN EFFECTS OF RADIATION EXPOSURE

- Skin effects are basically a good dosimeter. How much radiation someone has received is indicated by what type of skin changes have occurred.

    - At 300 rad, or 3 Gy, epilation occurs.
    - At approximately 600 rad, or 6 Gy, erythema occurs.
    - At approximately 1,000 rad or 10-20 Gy, dry desquamation occurs
    - At 2,000 rad or 20 Gy, moist desquamation occurs.
- Even in the worst exposures, it takes a few days for skin effects to occur. Gross symptoms typically take two weeks to appear when stem cells stop dividing and deficits of stem cell production occur.
- Skin injury visible immediately following a radiation event (other than that of erythema) should be attributed to a cause other than radiation.

DECONTAMINATION OF PATIENTS

External Decontamination

- Remove and bag clothing and shoes. I would recommend this as the main scene "decontamination." This removes about 80% or 90% of radioactive contamination.
- After removing clothes and shoes, decontaminate wounds first as they are a theoretical avenue for internal contamination.
- Decontaminate intact skin.
- Use gentle washing techniques and multiple washings if necessary.
- Confine all fluids from washing to prevent them from being a source for cross-contamination.
- Cover contaminated areas of patient with plastic wrap or bags until time is available to decontaminate.
- Handle foreign objects with care until proven non-radioactive with survey meter
- Cease decontamination:
    - When decontamination efforts produce no significant reduction in contamination
    - When the level of radiation of the contaminated area is less than twice background
    - Before intact skin becomes abraded

Internal Decontamination

- Radioactive material may enter the body through
    - Inhalation
    - Ingestion
    - Wounds
- Internal contamination generally does not cause early signs or symptoms
- Internal contamination will continue to irradiate the patient
- Agents used for internal decontamination
- Plutonium: chelating agents known as calcium and zinc DTPA; available from CDC pharmaceutical stockpile and through REAC/TS (Radiation Emergency Assistance Center and Training Site)

- Uranium: Alkalinization of urine to somewhere above 7.5 and 9.0
- Cesium, rubidium and thallium: Prussian blue
- Tritium: This radionuclide is usually found as a form of water; have patient drink radio-stable water to increase turnover of radioactive water from the body.
- Radioactive iodine: potassium iodide (K1)
    - Only helpful in special cases
    - KI saturates the thyroid gland with stable iodine
    - KI must used prior to or within hours of exposure to radioactive iodine

LONG TERM CONSIDERATIONS OF RADIATION EXPOSURE

- Neutropenia
- Pain management
- Necrosis
- Plastic/reconstructive surgery
- Psychological effects (PTSD)
- Counseling
- Dose assessments

KEY TAKE-HOME POINTS

- Stabilization is the highest priority.
- Radiation experts should be consulted.
- Training and drills should be offered.
- Adequate supplies and survey instruments should be stocked.
- Standard precautions (N95 mask if airborne particulates present) reduce personal contamination.
- Early symptoms and their intensity indicate the severity of the radiation injury.
- First 24 hours are the most critical.

QUESTIONS AND ANSWERS

Marguerite Neill, M.D.
Infectious Diseases Society of America

I'm wondering how this surveillance would work for recognition of a hidden source of radiation exposure?

Dr. Smith
That's a good question. For example, you have a hidden source in a public park or similar setting and, normally, one doesn't carry radiation survey meters around checking for things like that. I think the primary answer to your question is, if there is some intelligence, some kind of knowledge that there could be a possibility of something in the area, it would be very easy for

health physicists or radiation physicists to carry meters around in the area to see if there's any possibility of penetrating radiation.

Even helicopters can be used with radiation detectors to fly over areas where there might be a possibility of that. But that's a good question, and just like with other agents, biological and chemical, there could always be a covert source of public exposures that's unknown to us.

Dr. Baden
I'm sorry. Were you talking about surveillance in terms of long-term follow-up with patients? Is that correct?

Dr. Neill
No, I actually would be speaking more in the traditional clinical epidemiologic sense. Most clinicians at this point would have at least rudimentary knowledge of plague, tularemia, pox virus diseases, anthrax, etc., so that I think if they were to see a patient who was presenting with at least some aspects of those diseases it would trigger recognition that these might be in the differential and thereby activate the appropriate testing and call to the local health department, etc. I'm sitting here as a clinician trying to think to myself, what would be the putative appearance of a patient to an urgent care or physician's office that should make me think that they have an acute radiation syndrome since it would seem as though, initially, it would look very nonspecific, could look perhaps like gastroenteritis, an acute viral infection with pancytopenia. Am I correct or wide of the mark?

Dr. Fong
You're actually fairly correct. In radiation-accident history, sometimes severe exposures have been first mistaken as gastroenteritis. The skin lesions of people that have been seen on radiation accident patients, too, have been mistaken for pemphigus. So this is a problem. When you see an unusual cluster of illnesses, one must start doing some additional detective work in trying to see what happened.

A lot of times, with a hidden source, this is typically going to be a delayed reaction response. You're going to find out this sort of source after the event, and you're asking, "How do we detect the event?" That's not necessarily an easy thing to do, but after a while people will start putting two and two together, and people will start realizing that, "I was in the same area; I've been exposed." That's one interesting thing about the Goiania incident in Brazil in 1987, where a sealed radioactive source was brought home and exposed several family members. Finally, after many family members got ill, the grandmother brought the source to a public health department, brought the source, put it on the table, said, "This thing is killing my family." That was the first presentation, the first recognition to the public health system that there was a public health problem involving radiation.

So it is somewhat problematic here. You may have some erythema that might be a clue, but that may not be very obvious there either. But we must just have a stronger index of suspicion, and that's the case for a lot of these biologicals, too. They have a lot of nonspecific symptoms here, and they're all going to be a little bit difficult to detect in the initial going.

Dr. Rob Hendler
Tenet Health Systems
I just had an interruption during this fine talk. You related the skin effects to a radiation dosage, and I just wanted you to repeat those.

Dr. Fong
Epilation, hair coming out by its roots, occurs at approximately 300 rad or 3 GY. The erythema occurs at approximately 600 rad or 6 Gy. Some degree of desquamation occurs around the range of 10 rad or 1,000 Gy, and that would be dry desquamation, occurs at the lower levels of ten gray or 1,000 rads. Wet desquamation, that would be a transepithelial injury, a full-thickness injury, would occur somewhere at 20 Gy or 2,000 rad or above; and above that you can get regular necrosis of surrounding tissues and supporting elements as well.

Dr. Hendler
Thank you. The other comment I would make is, what's really good about this presentation is that our people in our hospitals, if they had this kind of information clearly given to them, it would absolutely tell them that the common methods of protection and decontamination within the limits of a hot zone and moving people out is really very low risk to them; and I don't think most health-care workers are aware of that.

Dr. Fong
Yes. That's the most important piece of information that needs to go around for healthcare professionals in the case of radiation events.

ADDITIONAL RESOURCES

Incident Assistance

- The Radiation Emergency Assistance Center/ Training Site (REAC/TS)
  - www.orau.gov/reacts/
  - Phone: (865) 576-1005
- The Armed Forces Radiobiology Research Institute, Medical Radiobiology Advisory Team (MRAT)
  - www.afrri.usuhs.mil/
  - Phone: (301) 295-0530
- The American Association of Poison Control Centers
  - www.aapcc.org/
  - Phone: (800) 222-1222

Books

- - *Disaster Medicine*; Hogan and Burnstein, 2002.
- - *Medical Management of Radiation Accidents*; Gusev, Guskova, Mettler, 2001.
- - *The Medical Basis for Radiation-Accident Preparedness*; REAC/TS Conference, 2002.
- - *National Council on Radiation Protection and Measurement Report No. 65: Management of Persons Accidentally Contaminated With Radionuclides*, 1980.
- - *National Council on Radiation Protection and Measurement Report No. 138: Management of Terrorist Events Involving Radioactive Material*, 2001.
- AFRRI Publications: *Medical Management of Radiological Casualties Handbook*; Jarrett, 2003, and Terrorism with Ionizing Radiation Pocket Guide
- Article: "Major Radiation Exposure - What to Expect and How to Respond," Mettler and Voelz, New England Journal of Medicine, 2002; 346: 1554-61.

Web Sites

- www.va.gov/emshg/ - Department of Homeland Security Working Group on Radiological Dispersal Device Preparedness, Medical Treatment of Radiological Casualties

- www.crcpd.org – Conference of Radiation Control Program Directors

- www.bt.cdc.gov/radiation/index.asp - Centers for Disease Control and Prevention Radiation Emergencies Page

- www.acr.org/flash.html - Disaster Preparedness for Radiology Professionals

- www.hps.org/ - The Health Physics Society

- www.fda.gov/ - The Food and Drug Administration