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RADIATION

Chapter Quick Links

Introduction

While radiation emergencies are rare, the thought of radiation exposure often engenders a high level of anxiety in healthcare providers and the general population. This is often disproportionate to the actual risk of exposure as most types of incidents would involve minimal levels of radiation. Hospitals should assess, equip, and prepare for specific risks in their community related to nuclear power plant operations, laboratory and industrial sources of potential radiological exposures, the risk of terrorist use of a radioactive dispersal device (RDD), and the potential for a nuclear detonation in their region. All hospitals should have some means of radiological detection available and an onsite source of advice and assistance (usually the facility Radiation Safety Officer). More robust resources are needed in communities where a greater risk of radiation incidents exists.

Fortunately, most radiological materials can be detected with the use of a simple detection meter and decontamination requires doffing clothes and using soap and water. This chapter summarizes key aspects of hospital radiation response planning.

Related Resources
Additional resources are available in ASPR TRACIE's Radiological and Nuclear and Hospital Patient Decontamination Topic Collections.

Radiation Basics and Incident Types

Familiarity with basic terms and types of radiation can bolster hospital radiation planning. It is important to understand the following differences between contamination and irradiation:

- External Contamination: Radioactive materials on the outside of the body that can be easily removed. Detection and elimination of external contamination is the focus of most hospital radiation response activities.
- Internal Contamination: Radioactive materials ingested or inhaled that are more difficult to

Related Resource
Many resources are available that explain the basics of radiation, the risks of exposure, and planning considerations for hospitals, including Hospital Activities During Radiation Emergencies, from ASPR's Radiation Emergency Medical Management webpage.

eliminate but, in some cases, can be mitigated with decorporation agents[1]

- Irradiation: Gamma radiation that has passed through the body. It leaves no residual particles or contamination with radioactive material, but significant damage may have been done and can only be assessed through laboratory testing.

Note that contamination and irradiation often coexist. Triage and stabilization of life-threatening injuries should be accomplished first. After life-threatening conditions are treated and the patient condition is stabilized, assessing external contamination with radioactive material and providing decontamination is a secondary priority. Based on the incident and the isotope involved, further testing may be needed to determine radiation effects on the body or detect residual incorporated isotopes that may require treatment.

There are different types of radiation[2]:

- α (alpha): Low energy particles released from the nucleus of some radioactive atoms like Polonium-210. They have low energy and are easily shielded (e.g., by paper or cloth) and cannot penetrate through the superficial layer of skin. Materials that solely release alpha particles are not a hazard to victims or healthcare providers unless the material *enters the body* by ingestion, inhalation, or through an open wound.
- β (beta): Medium energy particles that can be stopped by aluminum foil. Beta particles may penetrate several centimeters into the skin. Some materials that release beta particles could cause superficial radiation burns if deposited on bare skin. Particles entering the body by ingestion, inhalation, or an open wound can cause damage to the cells and internal organs.
- γ (gamma): High energy electromagnetic waves that can travel hundreds of meters in air. Waves travel through the body leaving no trace, as they have no mass. Shielding is a challenge, requiring lead or feet of concrete.
- Neutrons: High-speed nuclear particles that have an exceptional ability to penetrate materials. Neutrons are much less commonly encountered than the other types of radiation but damage tissues like gamma waves.

Related Resource
ASPR TRACIE's Major Radiological or Nuclear Incidents: Potential Health and Medical Implications provides additional considerations for planners.

There are four basic types of radiation incidents:

1. Laboratory, medical, or industrial exposure/contamination.
2. Nuclear power plant radioisotope release.
3. Radiological Dispersion Device (RDD), commonly referred to as a dirty bomb, although the material could be deployed without an explosion (Radiological Exposure Device [RED]). For the purposes of this chapter, RDD includes REDs.
4. Nuclear weapon detonation.

[1] Cassatt, D., Kaminski, J., Hatchett, R., et al. (2008). Medical Countermeasures Against Nuclear Threats: Radionuclide Decorporation Agents. Radiation Research. 170(4):540-548.

[2] U.S. Nuclear Regulatory Commission. (2020). Radiation Basics.

These incident types vary significantly in the number of persons involved and the effects on patients. This chapter is geared toward exposures to source materials in the workplace and RDD incidents. General information about the hospital impact of a nuclear detonation is available from other resources.[3]

Provider exposure is reduced by:

1. Time: The less time exposed to the isotope, the better. A specific task could be divided among several providers to decrease the potential radiation exposure level if it is significant (particularly at the incident scene).
2. Distance: Exposures decrease by a factor of four as distance is increased (e.g., doubling the distance between a source of radiation and provider will decrease the dose of radiation received four times).
3. Shielding: Alpha particles do not require specific shielding, but a filtering mask protects against inhalation. Clothing, including suits worn for decontamination activities, protects against beta particles. Gamma radiation is high energy – thick layers of concrete or earth can offer protection. Lead aprons do not offer protection against gamma radiation but lead containers can help contain high energy radiation sources.

Radiation Response Equipment

Several technologies for radiation detection may be used during the hospital contamination assessment process. Most of the following detectors reveal both beta and gamma radiation; alpha particle detection usually requires additional attachments/accessories:

- G-M counter: This includes the classic "pancake"' probe and detector combinations. G-M counters classically register both counts per minute (CPM) and energy (mRem/h) and are the mainstay of most radiation detection programs. Some simpler "frisking" devices register only CPM and are thus easier to operate and less expensive.
- Digital dosimeter: These pager-like devices register the current energy (e.g., mRem/H) on a digital display and usually have an alarm that sounds at a selected rate of exposure. This can help reassure the decontamination team that they are not being exposed to significant levels of radiation.
- Portal monitor: These monitors can be assembled as a walk-through frame (similar to those for metal detectors) or built into the ceiling or wall to allow entrance doorways to be monitored for gamma radiation. They usually have an alarm threshold. This can be very helpful to alert providers to an RDD incident by monitoring all persons coming into an emergency department entrance. Patients who have recently had nuclear medicine diagnostics or therapies may trigger these alarms. Portable models can be set up for patients to walk through to screen multiple persons rapidly.
- Gamma spectroscopy detectors: These more advanced devices detect and analyze the energy profile to provide isotope identification, allowing more targeted assessment and

[3] Hick, J., Weinstock, D., Coleman, N., et al. (2011). Health Care System Planning for and Response to a Nuclear Detonation. Disaster Medicine and Public Health Preparedness. 5(S1):S73-S88.

treatment. These devices do not inform initial decontamination activities. They are not considered necessary hospital equipment and are generally carried by hazardous materials (HAZMAT) and specialty response teams.

Every hospital should have some radiation detection equipment available. At minimum, a G-M counter (pancake probe or frisker) is recommended. Each of these devices requires annual calibration, and purchase and maintenance of them should be conducted by a radiation safety officer and the nuclear medicine department (if the hospital has one).

Personal protective equipment is important to prevent secondary contamination of providers, including preventing inhalation of radioisotopes bound to dust and particulates. Standard chemical protective suits and powered air purifying respirators (PAPRs) worn for HAZMAT decontamination are sufficient, but simple barrier gowns and surgical masks or N95 respirators also provide adequate protection during hospital patient assessment and decontamination.

Powdered detergent may be helpful for cleaning some areas of the body. Drapes/chux and Magill forceps along with gauze sponges are helpful for wound cleaning. If the detector surface of the probe used to evaluate patients has a screen on it, this should be covered by a plastic bag or glove to prevent contamination of the device (note this will prevent alpha detection for those detectors that are capable). Rolls of plastic sheeting (i.e., walk off construction sheeting) can help prevent the contamination that occurs when isotopes are tracked onto clean areas (including the floor plates of portable portal monitors).

Some hospitals serve as the receiving centers for specific nuclear power plants. These hospitals may have access to additional equipment either onsite or provided as a regional resource and will have specific response protocols established with the utility.

Screening and Decontamination

In addition to providing the decontamination team members with training on the radiation detection equipment and hospital policies and process, posters or placards illustrate the screening process and thresholds for managing radiological contamination.

Lifesaving treatment takes priority over radiological decontamination. Therefore, a patient who has sustained major trauma or has immediate airway issues should be moved directly into the usual treatment spaces for care. Clothing should be carefully controlled, bagged, and sealed during this process. Following stabilization, more definite radiological contamination evaluation can occur. Care provider gowns (or the provider, if a gown was not worn) should be surveyed for contamination as well.

Related Resource
Several resources provide algorithms for assessment and decontamination, including REAC/TS from the U.S. Department of Energy's Oak Ridge Institute for Science and Education.

Background radiation levels should be recorded to establish the baseline. Background levels will rise normally during decontamination activities. The threshold for decontamination is often set at 300 CPM or > 0.1mRem/h for small incidents but may be raised depending on the scope of the incident. The screening process should involve careful sweeps of the head, torso, extremities, and particularly the feet, which are often sources of isolated contamination. If inhalation of radioparticulates is suspected, nasal swabs may be obtained for analysis.

If open wounds are present, these need to be decontaminated and then dressed with impermeable dressings prior to full body soap and water cleansing. Depending on the situation, wound decontamination may occur before or after body decontamination, but it is critical to prevent wounds from being further contaminated by runoff from the body. Providers can use Magill forceps to avoid coming in direct contact with potential contaminants. Using forceps, healthcare workers can easily pick up soapy gauze sponges, swab them across the contaminated surface/wound once—without back-and-forth scrubbing—, and discard them. After 5-10 swabs, the wound should be reassessed. The goal is to remove as much contaminant as possible from any wound.

Soap and water cleansing of all contaminated surfaces should occur next. Wash water and contaminated disposables such as washcloths should be secured along with victim clothing until an assessment with a radiation safety officer can be made about the proper disposition of these items. Decontamination rinsate can pose an environmental hazard and may require special handling in accordance with local, state, and federal guidance.

Following decontamination, the patient should be resurveyed. If residual contaminant is present, consultation with a radiation safety officer, radiation physicist, or the poison control center should occur for further instructions on continued decontamination efforts. Once decontamination is completed, it is important to determine the type of isotope involved (this information should be available from the fire department) as this can help guide further assessment and treatment. Some isotopes have countermeasures that can speed removal from the body. Such countermeasures include Prussian blue for cesium and thallium or diethylenetriamine pentaacetate (DTPA) for americium, plutonium, and curium.

In general, decontamination team members should be limited to 5 rem (0.05 SV) exposure, though up to 25 rem (0.25 SV) is permitted for lifesaving activities. It would be very unusual to reach these thresholds in the process of providing assessment and decontamination. Most high energy exposures are from gamma irradiation at the incident site and not from residual contamination. Ideally, decontamination personnel should wear a dosimeter outside their suit and the results should be recorded on a medical surveillance form after completion of decontamination activities. If a digital dosimeter is not available or supplies are limited, consider providing badge dosimeters to each team member.

Exposure Assessment and Treatment

Acute radiation syndrome causes dose-dependent damage to different organs including the bone marrow, the gastrointestinal tract, the skin, and the neurological and cardiovascular systems. Providers should note that while vomiting is the most common indicator of significant radiation exposure, it may also be seen with head trauma, anxiety, and many other acute conditions.[4]

At this phase of the response, radiation experts should be engaged to guide further patient assessment and treatment. Hospital incident command should be initiated and a liaison officer appointed who will work with public health, HAZMAT, and emergency management subject matter experts during the ongoing response. Experts in the management of bone marrow injuries include medical oncologists and stem cell transplant specialists (many located in hospitals participating in the Radiation Injury Treatment Network).

It is critically important that the hospital not be the location of radiation screening for larger incidents such as after an RDD. Local emergency management and public health agencies should set up community reception centers where they can screen the affected population.[5] It is extremely rare during an RDD incident for radiation exposed persons to need acute medical care unless they also sustain traumatic injuries. Every effort should be made to avoid initial screening of persons at the hospital for contaminants as this is an unwise use of resources. However, if a patient presents to the hospital for care and has medical needs, the hospital should be capable of screening for contamination.

Biologic samples (e.g., urine, feces, blood) or a gamma camera can determine the activity of gamma ray-emitting radioisotopes and the need for medical countermeasures.

Absolute lymphocyte counts (ALC) are one of the easiest and best predictors of bone marrow injury. However, several counts over time are generally required to estimate the dose of radiation received by the patient and the expected severity of the illness.

Patients with significant bone marrow injury may benefit from cytokines that increase production of neutrophils. Hospitals that provide oncology treatment may have some of these medications and they are part of the Strategic National Stockpile for use after a nuclear detonation incident. Chelating agents (e.g., calcium or zinc DTPA and Prussian blue) that are indicated for specific isotopes that may comprise an RDD are available through some state stockpiles and the Strategic National Stockpile. The hospital should coordinate closely with public health, poison control/toxicologists, radiation health physicists, and emergency management on the request and use of these treatments.

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[4] In a nuclear incident with thousands of casualties, symptom triage may be necessary, e.g., the "EAST" triage system.

[5] Centers for Disease Control and Prevention. (2024). Community Reception Centers.

Though often mentioned for radiation treatment, potassium iodide (KI) only protects the thyroid gland against uptake (incorporation) of radioactive iodine elements. Radioactive iodine is primarily a concern in nuclear power plant incidents and stockpiles are held (or distributed to those living) in close proximity to a nuclear plant for this purpose. To be effective, KI must be taken before exposure or within a few hours of the incident. KI offers no protection against injury from other isotopes.

For patients with significant suspected or confirmed gamma irradiation and those requiring chelation the hospital should provide supportive care, obtain serial absolute lymphocyte count (ALC), and consult with oncologists/radiation health physicists to guide ongoing treatment.

Hospital-based Occupational Exposures

If the hospital provides nuclear medicine treatment or diagnostics, the department should have a plan to respond to a spill or exposure/contamination of a technologist. Ideally, decontamination of any exposed skin should be performed in the radiology department. In unusual cases, the emergency department may provide decontamination support. An incident involving a high energy research or radiotherapy source is very unusual. In the event this occurs, the hospital should contact the fire department and initiate a HAZMAT response. The area should be secured, and evacuation of the surrounding care/work areas may be necessary. The hospital radiation safety officer should be contacted immediately and work with public safety on the response needs. Hospital incident command should also be activated for any incident involving a high-energy source.

Conclusion

Radiation incidents are extremely rare but can have significant consequences for both patients and the hospital, are a source of anxiety, and must be prepared for in advance. Therefore, having equipment, trained staff, and protocols that are clear, concise, and easily referenced in the decontamination area is important to ensure proper assessment and treatment of those exposed to radioisotopes. Following initial survey and decontamination, the hospital should consult with a radiation safety officer and other experts to determine the need for further care.