Major Radiological or Nuclear Incidents: Potential Health and Medical Implications

October 2022

Purpose and Scope

This ASPR TRACIE document provides an overview of the potential health and medical response and recovery needs following a radiological or nuclear incident and outlines available resources for planners.

The list of considerations is not exhaustive but does reflect an environmental scan of publications and resources available on past incident response, exercises, local and regional preparedness planning, and significant research and policy publications. Those leading radiation preparedness, response, or recovery efforts may use this document as a reference, while focusing on the assessments, needs, and issues specific to their communities.

Entities engaged in planning for or responding to radiological incidents should consult with the radiation protection authorities in their state in addition to federal resources. Most states and local jurisdictions have existing plans for responding to radiological incidents and these plans can provide local information for health and medical providers.

For more in-depth information on preparing for, and responding to, a radiological or nuclear incident, see the following ASPR TRACIE resources: Radiological and Nuclear Topic Collection, Healthcare Coalition Radiation Emergency Surge Annex Template, and Select CBRN Resources. Key resources from the TRACIE collection and additional resources such as the U.S. Department of Health and Human Services (HHS) Radiation Emergency Medical Management (REMM) and the Centers for Disease Control and Prevention (CDC) Radiation Emergencies sites are listed within and at the end of the document.

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Background Information

Radiation and nuclear emergencies may be accidental or intentional and can have wide-ranging effects on the healthcare system. Each type of event has different implications for planning and response. Table 1 compares and contrasts these different incidents and highlights healthcare system impacts across this spectrum of incident type.

This resource focuses on the impact to the healthcare system, with additional, broader public health and community recovery considerations that may tangentially affect healthcare discussed in the section titled Long Term Considerations and Recovery.

Types of radiation incidents include:

- Worksite exposure
- Covert individual assault/attempted assassination
- Nuclear power plant
- Radiological Dispersal Device (RDD) / Radiological Exposure Device (RED) (intentional)
- Nuclear detonation

Radiation terminology and information can be confusing when not used regularly. Appendix A: Radiation Terminology contains information on:

- Types of Radiation
- Exposure and Dose
- Dose Equivalencies/Comparisons
- Radioactive Isotopes and Byproducts
- Radiation Detection

Table 1: Incident Type Comparisons

Incident Type	Description	Known Isotopes?	Size of Impact	Healthcare Facility Protective Measures	Healthcare System Considerations/Impacts			
					Loss of Facilities/Critical Systems	**Mass Casualty**	**Exposure Tracking**	**Injury/Illness Patterns**
Worksite Exposure	Unintentional event causing the release of radioactive isotopes in an industrial or medical facility that regularly uses the materials Could also include accidental release following an incident involving the transport of radioactive material	Yes. The facility would know the isotopes and be familiar with the treatment, decontamination procedures, and countermeasures.	Small or limited, usually just a few people exposed	Personal Protective Equipment (PPE) appropriate for exposure and job classification It is possible that the patient could present to a medical facility after gross contamination.	Unlikely	Unlikely	Could potentially need to track or trace exposure if detection was delayed and secondary contamination occurred	Skin, eye irritation, burns, inhalation, and internal contamination, acute radiation syndrome (ARS) in a few cases. Most exposures are very low-level.
Covert Individual Assault / Assassination Attempt	The use of radioactive isotopes for covert assault / assassination has occurred. The perpetrator and the intended victim could be exposed, in addition to anyone else in the vicinity of the victim or the exposure source – usually an ingested isotope. Refer also to radiological exposure device section.	No. Testing would be required and radiation exposure would not necessarily be obvious.	Small or limited, usually just a few people exposed	PPE appropriate for exposure and job classification	No	Unlikely	Could potentially need to track or trace exposure if detection was delayed and secondary contamination occurred	Skin, eye irritation, burns, acute radiation syndrome (ARS) depending on source / route / level of exposure
Nuclear Power Plant	Could include accidental release of materials, or accidental or intentional failure of or damage to reactor/safety systems, potentially leading to core meltdown. Large scale release of radioactive isotopes is rare. In most instances release of isotopes is contained and restricted to facility personnel.	Includes multiple byproducts, depending on the isotope being used on site including: Iodine-131, Strontium-90, Cesium-137, Plutonium-239	On-site release may be confined to a single space. Significant atmospheric release usually limited to a roughly 10-mile radius and downwind. Many more people will seek evaluation or treatment than are affected.	Evacuation or shelter in place if directed by authorities. PPE likely only needed for power plant response/ recovery	Facilities within the evacuation zone of a nuclear power plant could be required to evacuate or shelter in place, in which case they may be inaccessible. If there is significant radiation exposure, those	Possible	Geographically based Reception centers needed	Acute radiation syndrome (ARS) unlikely but possible. Most exposures low-level. Population doses from this type of release may be associated with long-term health effects. Note the Chernobyl release was initiated by an explosion at a reactor that had basically no containment for an inextinguishable fire from the graphite core

Incident Type	Description	Known Isotopes?	Size of Impact	Healthcare Facility Protective Measures	Healthcare System Considerations/Impacts			
					Loss of Facilities/Critical Systems	Mass Casualty	Exposure Tracking	Injury/Illness Patterns
					facilities could be closed indefinitely.			leading to much higher exposures compared to the Japan Fukishima reactor meltdowns. Blast and burn injuries possible at the plant. Injury potential from evacuation-related accidents Population-wide mental health concerns People should not use potassium iodide (KI) unless directed to do so.
Radiological Dispersal Device **Radiological Exposure Device**	Radioactive substance left where it can passively expose people (exposure device, i.e., RED) or in the form of a "dirty bomb" (dispersion device - RDD), where radioactive isotopes would be added to a conventional explosive blast, with radiation contamination of the blast radius. RDDs do not cause "fallout." RDD can also be non-explosive with food, water or other contamination. This could be a challenge to determine a Time-Zero (start of incident) and even location.	No. Testing would be required. May be mixed radionuclides to cause confusion. Nine isotopes are available in concentrated amounts and/or can be easily obtained for potential RDD use: o Americium-241 (Am-241) o Californium-252 (Cf-252) o Cesium-137 (Cs-137) o Cobalt-60 (Co-60) o Iridium-192 (Ir-192) o Plutonium-238 (Pu-238) o Polonium-210 (Po-210) o Radium-226 (Ra-	Limited to the affected area of the blast and debris, based on amount of explosive Depending on type of device may have radioactive shrapnel, and a limited plume. Primary hazard is blast and fragmentation injuries in the immediate area of the blast. Many, many more people will seek treatment than are actually affected.	Evacuation or shelter in place if directed by authorities. PPE appropriate for exposure and job classification (including HEPA/N95 respirator)	Facilities within the affected area could be contaminated and be closed until remediated. For non-explosive event an investigation is needed to determine site, time, and dose of exposures.	RDD explosion may injure many persons, RED may expose many persons but casualties unlikely.	Geographic and exposure-based tracking needed Reception centers needed	Skin, eye irritation, burns, acute radiation syndrome (ARS) unlikely but possible if radioactive shrapnel present and depending on isotope, time/distance/shielding. External contamination requiring decontamination likely from RDD Internal contamination possible from inhaled radioactive dusts. Population-wide mental health concerns

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		226) o Strontium-90 (Sr-90)	A non-explosive contamination could affect many people with widespread concern (e.g., milk supply).					
Nuclear detonation	A massive explosion caused by fission of nuclear material.	Near the blast, will include prompt radiation dose from gamma rays and neutrons. Dangerous fallout is produced by fission products and neutron-induced radionuclides and may travel many miles. It may include hundreds of isotopes of which 19 are most likely to affect people's health. Relatively rapid decline in dose rate	Yield-dependent but capable of destroying majority of a city vs. multiple city blocks.	Shelter in place then evacuation as directed by authorities. If in dangerous fallout area, use building to shield and reduce exposures while sheltering. PPE appropriate for exposure and job classification (including HEPA/N100 respirator) Screening needed for people entering hospital/shelter "clean" areas	Facilities within the affected area could be damaged or contaminated and be closed temporarily or permanently. Severe infrastructure damage is likely. Utility and communication outages likely.	Yes Triage of casualties very important to avoid overwhelmin g medical capabilities. First 24-48h focus on trauma care, then radiation injury assessment / care and patient transfer.	Geographic and plume-based Fallout plume can travel many miles. High altitude dissemination can cause far-reaching effects. Assembly (screening centers) and triage / treatment areas needed – reception centers needed in receiving communities.	Trauma, burn, and radiation injuries may be isolated or combined depending on location of patient. Blast injuries, burns, crush injuries, skin, eye, and lung irritation Pressure induced injuries – ear drums, lungs, impact Pressure related injuries from blast wave Flash injuries to eyes ARS and other radiation related sequelae CERTAIN in many casualties Responder exposure thresholds should be observed Population-wide mental health concerns

Health and Medical Considerations

> When dealing with any type of radiation incident, the highest priority is to ensure lifesaving emergency care is administered *first* and contamination/ exposure is addressed second.

Impacts to the Healthcare System – Overview

As noted in Table 1, the impact on the healthcare system varies depending on the incident type. Radiological incidents can affect a single person after an industrial exposure, or affect millions after a nuclear detonation, with catastrophic impacts on the healthcare system infrastructure. This document contains resources for all incident types but is focused on larger scale or catastrophic incidents. Impacts and considerations are discussed in subsequent sections.

When dealing with any type of radiation incident, the highest priority is to ensure lifesaving emergency care is administered first and contamination/exposure is addressed second. Residual radiation contamination on patients is seldom a threat to providers, so treating injuries should take precedence over performing radiation screening and decontamination. The immediate concerns for healthcare system affected by a radiological or nuclear incident are personnel/facility safety and early patient triage, treatment, and transport. Clinical management and personal protection issues are described later in this document. The primary, initial focus will depend on the incident type:

- RDD/dirty bomb–focus is on blast injury management and **detection and decontamination of minor residual external and potential internal contamination**. High-level gamma exposure is unlikely when associated with a device that uses radioactive material in powder form. However, caution should be exercised if it is apparent that radioactive shrapnel may have been dispersed. Certain types and forms of radioactive shrapnel may have extremely high radiation dose rates (e.g., Cobalt 60) that could result in a significant absorbed dose for victims and responders. For a non-explosive radiologic exposure device (RED), the fear of radiation exposure, and the need for mitigation will likely produce a surge of concerned individuals.
- Nuclear detonation – focus is on initial trauma care and then **assessing and managing high levels of absorbed radiation** (i.e., radiation injury from contamination is usually minimal compared to the high doses of gamma radiation that may have been absorbed from the blast or fallout). Injuries occur from the initial blast as well as initial release of radiation (prompt radiation) and deposition of radioactive debris from the blast (fallout). Depending on whether the patient was exposed to blast wave, heat, or radiation, they may have any combination of injuries including isolated trauma or isolated radiation injury. Residual environmental contamination is widespread, but a minor concern compared to finding patients with acute radiation syndrome from irradiation (gamma radiation that the body absorbed but with no residual contamination). There are multiple issues and priorities, which are highlighted in the article Health Care System Planning for and Response to a Nuclear Detonation and discussed in this section.

KEY CONCEPTS

- Rescue and emergency trauma care take precedence over radiological assessment and decontamination (as opposed to chemical events where decontamination is first priority).
- Nuclear and radiological incidents can be safely managed using emergency responders' equipment and protocols.
- Standard infection control precautions including use of standard respirator masks are generally sufficient for treatment of victims of radiological incidents.
- Being contaminated is rarely life-threatening.
- Being exposed to radiation does not make an individual radioactive.

Following a nuclear detonation, after initial trauma management, healthcare system considerations and impacts include:

- **Overwhelmed healthcare system** – Damage to hospitals, communication capabilities, EMS, and other critical infrastructure can cripple healthcare response efforts at a time when an overwhelming number of victims (including first responders) will need acute medical care. Triage/treatment casualty collection points should be established and resources brought-in to support compromised infrastructure. The **R**adiation-specific **TR**iage, **TR**eatment, **TR**ansport sites (RTR) system should be considered as a framework for the initial healthcare response. Many people will flee the affected area and seek care in communities up to hundreds of miles away.
- **Sheltering orders** – Because the fallout is likely to place hundreds of thousands of persons at risk, sheltering orders for those in the plume area should be issued immediately and will affect healthcare facilities and the healthcare response. Sheltering is extremely effective at limiting radiation exposure and is usually continued for 24 hours, until radiation levels fall significantly (refer to A Decision Makers Guide: Medical Planning for a Nuclear Detonation, Second Edition).
- **Need to identify population at risk** – Thousands of people will die from radiation illness, but the number can be greatly reduced if affected individuals are identified and receive early treatment (e.g., with antibiotics to control infections and cytokines to support white blood cell production in the injured bone marrow). Because Absolute Lymphocyte Counts (ALC) may not be available, clinical triage criteria may need to be used to screen victims at community-based Assembly Centers (e.g., the Exposure and Symptom Triage Tool). Many patients will have limited initial symptoms (particularly vomiting) and then feel well for days to weeks before developing infections and other complications that can lead to death if not aggressively treated. Triage is essential, as many patients will survive without interventions (< 2 Gy / 200 rad exposure) and many will die despite aggressive support (> 6 Gy / 600 rad exposure) the priority is determining those with moderate exposure that can most benefit from treatment.
- **Patient movement** – Early on, most patient victim movement will be self-evacuation. Once the exposed population has been identified, they should be moved or directed to areas that have greater healthcare capacity, particularly those with moderate absorbed doses. Because they should be in the latent phase of illness, with relatively few

symptoms, most can be transported by usual means (airplane, train, bus). Nuisance contamination should be detected and eliminated by decontamination prior to transport.

- **Extensive geographic area impacted** – The impacted area expands far beyond the immediate area of detonation. Broken windows and structural damage can extend for miles and the radiation plume will follow the predominant weather/wind patterns for long distances. This large area of impact can make mutual aid and resource sharing difficult. However, using radiation dose assessment, many areas will have low (and decreasing) radiation exposure so that responders can safely operate there by monitoring exposure rates and following thresholds under the Protective Action Guidelines.
- **Psychological impact** – Any emergency, including those involving radiation, can cause psychological distress. Radiation is a complex and unfamiliar topic to many people, which make the psychological effects of a radiation disaster more severe. Monitoring and treating mental and physical symptoms during a radiation emergency is important for short- and long-term mental health. Many symptoms of severe psychological stress are similar to those of acute radiation syndrome (vomiting, headache, dizziness, trouble concentrating).

Clinical Management Considerations

Personal Protective Equipment and Responder Safety and Health

It is highly unlikely that response to radiation events will result in substantial risk to first responders and receivers unless in the immediate aftermath of a nuclear event close to the detonation. Experience has shown that medical workers providing care to the contaminated victims of a radiological incident are unlikely to exceed the occupational dose limits for a radiation worker, 50 mSv (5 rad). Medical personnel near the Chernobyl nuclear reactor accident who treated contaminated workers accumulated doses < 10 mGy (1 Rad).

As discussed in the Exposure and Dose section of this document, **time, distance, and shielding** are the key components to reduce radiation exposure. Safety Officers at the scene of an incident will need to establish perimeters based on the environmental readings and first responders should have dosimeters to monitor their exposure rate. HHS REMM provides information from various sources on radiation control zones and perimeters for responders. Protecting the safety and health of emergency responders is critical. Note that some dose thresholds apply to exposure over a sustained time period (up to years or even a lifetime). They are additive, and not limits that “reset.” In general, acute exposure to more than **5 rad** should be avoided, though 25 rad in lifesaving situations is an appropriate ceiling. Radiation levels after a nuclear incident fall off rapidly over time; local radiation levels can vary greatly depending on the type of incident/device involved, weather patterns, and the types of structures surrounding the incident.

> Note: **time, distance, and shielding** are the key components for preventing or reducing radiation exposure.

Guidance on REMM for Personal Protective Equipment in Radiation Emergencies includes:

- In a radiation emergency, the choice of appropriate personal protective equipment (PPE) depends on:
    - Response role and specific tasks (e.g., responder to the site vs. those performing decontamination at a reception center)
    - Risk of contamination
    - Type of contamination (e.g., contact, inhaled, as well as isotope factors)
- PPE can protect against:
    - External contamination
    - Internal contamination via inhalation, ingestion, absorption through open wounds
    - Other physical hazards (e.g., debris, fire/heat, or chemicals)
- PPE **cannot** protect against exposure from high energy gamma radiation, a highly **penetrating** form of ionizing radiation, which can occur from blast and fallout.
    - Lead aprons worn in diagnostic radiology do not provide significant shielding against gamma radiation and are impractical.
    - See Types of Ionizing Radiation and Shielding Required
- Equipment should include a personal radiation dosimeter (ideally digital readout with alarms) whenever there is concern about responder exposure.
    - Direct-reading personal radiation dosimeters may be used to monitor radiation dose and can help workers stay within recommended Dose Limits for Emergency Workers.
    - Direct-reading dosimeters should be worn so that a worker can easily see the read-out and/or hear warning alarms.
    - When there are not enough dosimeters, the captain/leader of each area should have a personal dosimeter that should be checked frequently.
- Recommended respiratory PPE when respirable particles are present include a full-face piece air purifying respirator with a High Efficiency Particulate Air (HEPA) filter (e.g., N100/P100).
    - Other respiratory protective equipment (e.g., a simple surgical facemask), non-fit tested respirators, or ad hoc respiratory protection may not deliver sufficient respiratory protection, though any protection is better than none – the less inhaled particles the better – and most particles are larger dusts that do not require the highest level of filtration.

Environmental testing and hazard assessment by a safety professional can help identify hazards and risk levels and direct choices of appropriate PPE. Immediate life-saving activities should not be delayed for determination or distribution of PPE.

Nuclear Detonation Incident Note: Responders in the dangerous fallout zone should shelter with the rest of the population until monitoring demonstrates it is safe to resume response.

For More Information:

- ASPR TRACIE Responder Safety and Health Topic Collection
- ASPR TRACIE Tips for Retaining and Caring for Staff after a Disaster
- ASPR TRACIE Healthcare Challenges After Radiological Incidents
- EPA: Protective Action Guides (PAGs)
- Field Guide for Health and Safety Officers: Radiological Incidents
- HHS REMM: Personal Protective Equipment in a Radiation Emergency
- IND Health and Safety Planning Guide for Planners, Safety Officers, and Supervisors for Protecting Responders
- IND Quick Reference Guide for Planners, Safety Officers, and Supervisors for Protecting Responders

Health Effects of Ionizing Radiation

Exposure to high levels of radiation can cause two kinds of health effects: deterministic effects and stochastic effects.

- Deterministic effects are predictable and dose-related manifestations like Acute Radiation Syndrome (ARS) with symptoms of vomiting, diarrhea, headache, fever, skin burns, hair loss, or death. Some deterministic effects occur later (e.g., lung injury).
- Stochastic effects are long-term and variable effects such as cancer. The risk of occurrence (i.e., probability) increases in relation to the dose received, however, it is difficult to predict specific outcomes for an individual. The severity of the cancer or sequelae does not depend directly on the dose, though factors such as dose, target organ, and underlying susceptibility do impact likelihood of negative outcomes. Younger persons are more likely to experience stochastic effects simply because they have more years to develop them.

> Treating patients during the latent phase of ARS improves survival.

Radiation dose determines the severity and extent of deterministic effects and the probability of developing stochastic effects.

For More Information:

- CDC Radiation Emergencies, Information for Clinicians
- Dose Estimator for Exposure Tools
- Health Physics Society: Specialists in Radiation Protection
- Information for Health Care Personnel
- Medical Management of Radiation Incidents
- Oak Ridge Institute Dose Estimation
- USDA Radiation Safety: Dose Limits

Short-Term Health Effects (Deterministic Effects)

Acute Radiation Syndrome (ARS) and Cutaneous Radiation Injury (CRI) are the two primary short-term health effects.

Acute Radiation Syndrome

ARS is an acute illness caused by a high dose of penetrating radiation to the whole body in a short period of time. Note that *all* patients with possible ARS should have an absolute lymphocyte count (ALC) obtained as soon as possible for more accurate prediction of dose and risk. Unless very severe (in which case symptoms progress rapidly to death), most ARS follows three phases: initial symptoms appear within the first hours to days, then a “latent period” occurs without many symptoms (this may last a few days to a few weeks), then infections and other complications set in as the existing white blood cells die and are not replaced due to bone marrow injury. Delayed deaths usually occur from infection as the body has no white blood cells to protect it, and damage to organs allows intestinal bacteria into the bloodstream. Damage also occurs to the vascular system and there can be a loss of platelets. Both may contribute to abnormal bleeding. If patients can be treated during the latent phase, they have an improved chance of survival.

As the dose increases, there are four general clinical manifestations of ARS; hematopoietic, gastrointestinal, cutaneous, and neurovascular syndromes. Each is described next and hyperlinked to the HHS REMM Managing ARS Tool.

Hematopoietic

- Hematopoietic effects are dose dependent and there is good correlation with the amount of whole-body radiation received and changes in blood cell counts (particularly absolute lymphocyte count or ALC). Significant effects on cell counts are usually seen above 1 Gy (100 Rad) exposures.
- Bone marrow is damaged by radiation. Some of the white blood cells (granulocytes, monocytes) in circulation survive the exposure, but are not replaced if the damage is significant. This is what causes an increased risk of infection in the weeks following exposure.
- Effects can be partially mitigated with early administration of cytokines that stimulate bone marrow production of new cells; this is most effective the first few days post radiation exposure.
- Antibiotics should be given prophylactically to prevent infection in significant ARS cases, and any infection should be aggressively treated with broad spectrum antibiotics.
- Blood products may be needed to support lost components – platelets in particular may be needed.

Gastrointestinal

- Nausea and vomiting are the most common ARS symptoms (although many other factors can contribute to nausea and vomiting, including stress, viral/food related illness, and head injury). Threshold for vomiting is usually around 1-2 Gy/ 100-200 Rad.
- Diarrhea, cramps, and stomach pain are seen in higher level exposures.
- Gastrointestinal bleeding can be an early or late complication that may require transfusion.
- Anti-emetics and anti-diarrheals may be helpful to control symptoms and allow hydration.
- IV fluid replacement may be needed.

Cutaneous

- Skin changes from radiation injury can occur hours to weeks after exposure and include redness, swelling/edema, blistering, and sensitivity. Thermal burns may also occur and may co-exist with radiation burns.
- These effects generally reflect a poor prognosis if significant areas are involved due to the direct correlation with substantial radiation exposure. These burns are frequently seen on skin exposed to high levels of fallout radiation.
- Late skin changes include skin sloughing and loss, hair loss, changes to the nails and nail beds, and ulcers or necrosis.
- Topical treatment is symptom dependent and may include protectant dressings, anti-inflammatory glucocorticoids, antihistamines, antibiotics, and drying agents.
- Pain management is an important component of treatment.
- Use debridement, dressings, skin grafts, and burn consultations, as appropriate. Surgical procedures are safest when performed in the first few days after exposure as high infection and complication (e.g., poor healing) rates accompany later procedures.

Neurological

- Fluctuating blood pressure and body temperature (particularly fever) may occur at higher exposures (although causes other than ARS should be considered).
- Fatigue, headache, and lack of appetite are common post exposure side effects
- Cognitive and neurological deficits can also occur hours to weeks after significant exposure, usually beginning with confusion.
- Neurologic symptoms generally have a worse prognosis and are rarely seen without severe GI symptoms. The earlier the onset of neurologic symptoms, the worse the prognosis. However, many ARS neurological affects (other than fever) overlap with stress syndromes and lack of sleep.
- Manage symptoms: analgesia, anti-emetics, fluid management, glucocorticoids, and hypertonic solutions (if increased intracranial pressure), temperature control, blood pressure.

  For More Information:

  - CDC Acute Radiation Syndrome: A Fact Sheet for the Public
  - CDC Acute Radiation Syndrome: A Fact Sheet for Physicians
  - REMM Exposure: Diagnose/Manage Acute Radiation Syndrome
  - RITN Radiation Patient Treatment AFRRI Pocket Guide
  - HHS REMM: Managing Acute Radiation Syndrome
  - Radiation Injury Treatment Network® (RITN)

Cutaneous Radiation Injury

Cutaneous Radiation Injury is different than cutaneous subsyndrome of ARS in that it does not occur with ARS and can be from more localized radiation exposure or from exposure that did not penetrate beyond the skin (e.g., "beta burns"). These radiation injuries are different from thermal or chemical burns in that they can manifest later and can result in malignancy. Treatment, however, is similar to cutaneous ARS or thermal burns.

For More Information:

- CDC Cutaneous Radiation Injury
- CDC Cutaneous Radiation Injury: A Fact Sheet for Physicians
- HHS REMM: Cutaneous Subsyndrome

Long-Term Health Effects (Stochastic Effects)

Cancer, prenatal radiation effects, and disaster behavioral health issues are the primary long-term health effects that victims face after radiation exposure.

Cancer

Some population data indicates a slight increased risk of some cancers in areas that have experienced past radiation exposure, but the numbers are far less than what is assumed among the lay public. These cancers include leukemia, breast, bladder, colon, liver, lung, esophagus, ovarian, multiple myeloma, stomach, prostate, nasal/sinus, pharyngeal, laryngeal, and pancreatic.

Currently in the U.S., approximately 40% of the population will experience cancer and 23% of the population will experience a fatal cancer. A radiation dose of 25 rad (0.25 Gy) would increase the average individual lifetime risk of fatal cancer from 23% to 24.8%, or by 1.8%. Similarly, a dose of 100 rad (1 Gy) would increase the average individual lifetime risk of fatal cancer by 8%.

For More Information:

- CDC: Cancer and Long-Term Health Effects of Radiation Exposure and Contamination
- U.S. Nuclear Regulatory Commission: Radiation Exposure and Cancer

Prenatal Radiation Exposure

The effect of radiation on a fetus is based on the amount of radiation exposure that occurred and the gestational age of the fetus. Fetuses are particularly susceptible to radiation-induced organ damage between 2 and 18 weeks gestation. Negative health effects could include stunted growth, deformities, abnormal brain function, or cancer later in life. Pregnant women who are exposed to levels of radiation over 20 Rad may have a higher risk of miscarriage.

For More Information:

- CDC: Cancer and Long-Term Health Effects of Radiation Exposure and Contamination
- CDC Infant Feeding and Pregnancy
- EPA Radiation Health Effects
- NRC Radiation and Its Health Effects

Disaster Behavioral Health Needs

Disasters can lead to significant mental and behavioral health consequences that will directly impact healthcare systems and responders. The demand for disaster behavioral health services spikes immediately following an incident and decreases but continues over time.

Radiological emergencies are frightening for most people, including first responders, healthcare personnel and their families. The health effects, exposure risk, and general recovery from these incidents are not well understood by the general public and will likely cause significant psychological stress including in areas not directly affected by the incident. The scale and emotional impact of a radiation event—particularly a nuclear detonation—will have profound psychological effects beyond usual disaster incidents. Past incidents provide some information on how the general public will react to radiological emergencies. Ensuring a disaster behavioral health program is in place, along with a rapidly deployed risk communication program to explain the exposure and risks and calm those outside the affected area, will be critical to preserve healthcare system resources.

For More Information:

- ASPR TRACIE Disaster Behavioral Health: Resources at Your Fingertips.
- ASPR TRACIE Mental/Behavioral Health (non-responders) Topic Collection.
- ASPR TRACIE Responder Safety and Health Topic Collection.
- ASPR TRACIE Tips for Retaining and Caring for Staff
- HHS REMM Mental Health Professionals
- SUNY Disaster Mental Health: Assisting People Exposed to Radiation (manual)
- SUNY Disaster Mental Health: Assisting People Exposed to Radiation (slides)

Decontamination

If radioactive contamination exceeding the criterion established by local authorities is detected, individuals and their belongings should be decontaminated before entering shelter or hospital clean zones. The contamination threshold is established by responding jurisdictions and can vary based on incident specifics as well as background radiation levels. Truly "clean" patients may not be a reasonable goal, particularly in shelters after a large incident. For example, after the Fukushima disaster 20,000 counts/minute was considered adequately clean to enter shelters.

Unlike many chemical and biological agents, radioactive material contamination rarely represents an immediate danger to the health of the victim or the responder. This reduces the immediacy of the need for decontamination and allows greater flexibility in selecting decontamination options. A scalable approach is required for decontamination planning. Because radionuclide contamination is not likely to be an immediate health threat to the victims, the size of the incident will determine the type of decontamination procedures that can be employed. Contamination control will likely not be possible during the early (emergency) phase of an incident and minor contamination of a treatment area should not prevent its use. However, reasonable attempts should be made to limit the spread of contamination (e.g., patient clothing control, covering contaminated surfaces with plastic). If an area such as a room in a hospital emergency department designated for the reception of contaminated injured patients becomes heavily contaminated, performing limited decontamination of the area will reduce the doses received by caregivers and limit the spread of contamination to other areas.

People without injury who were in an at-risk area should perform self-decontamination at home during a large-scale incident by undressing at the entry to the home, bagging clothing in a sealable plastic bag, showering with usual household soap and water and then reporting for further evaluation to an assembly center (triage post-nuclear) or reception center (assessment after low level exposure event) to be screened for contamination with hand-held or portal monitors. Decontaminating a person can be as simple as removing an article of clothing or it can require multiple showers or special techniques to remove stubborn contamination. In general, people can be cleaned as if they were covered in dust or mud. Always check the soles of the feet for contamination, as walking through a contaminated area is common! Clothing may need to be brought to the screening center for assessment. Assessment for internal contamination is more complex and may require nasal swabs, sampling of urine or stool, or in some cases specialized scans in a hospital.

Radiation safety experts will assign thresholds for clothing contamination. Most clothing should be able to be washed and re-used, but some with higher levels of contaminant may have to be destroyed.

Organizations with emergency-response vehicles, particularly ambulances, should recognize that complete contamination control is not possible during the early (emergency) phase of an incident and that minor contamination of a vehicle's interior should not prevent or delay its use. However, reasonable attempts should be made to limit the contamination inside a vehicle. To minimize contamination of the interior of an ambulance:

- Remove outer clothing of a contaminated patient before loading into an ambulance;
- Place two sheets on the gurney before placing a contaminated patient; and
- Fold the edges of sheets over the patient as a “cocoon.”

Reasonable attempts should be made to reduce the amount of radionuclide contamination inside a vehicle after a task, such as transportation of a contaminated injured patient to a hospital. These measures will reduce exposure for people working in the vehicle.

Universal precautions (i.e., standard hospital personal protection procedures) in the emergency room are generally sufficient for treatment of victims of nuclear or radiological incidents.

On-scene personnel that may be exposed to respirable dusts should use respiratory protection. Radiation safety professionals will help determine any appropriate decontamination procedures specific to the isotope.

The following section lists high-level, immediate actions for gross decontamination. Healthcare practitioners should follow the Radiation Treatment Protocol from the Radiation Emergency Assistance Center (REAC/TS) for specific actions and care pathways.

If running water is available:

- People should first be quickly and effectively spot decontaminated by using material such as baby wipes to reduce the amount of contaminated wash water.
- Carefully removing the outer layer of clothing can greatly reduce the contamination.
- If clothing removal and spot decontamination efforts are not effective, then wash exposed skin at a sink or shower with soap and water.
- Do not allow wash water to run into lacerations. Cover deeper wounds prior to decontamination and then selectively assess and decontaminate them to avoid internal contamination.
- Do not allow wash water from hair to run down the body into creases to avoid contamination of skin crevices (i.e., bend over toward shower stream to wash hair).

If running water is NOT available:

- Practice dry decontamination techniques that focus on clothing control. Tape or lint rollers may be used to remove visible dust from clothing or skin.
- Carefully remove the outer layer of clothing and decontaminate exposed skin with moist wipes, damp towels, or other available methods.
- Use the "single wipe" technique (wipe and discard); do not scrub or wipe back and forth across the same area to avoid spreading contaminant.

For More Information:

- ASPR TRACIE Hospital Victim Decontamination Topic Collection
    - Radiological-specific decontamination resources are also available under a separate heading in this Topic Collection.
- ASPR TRACIE Pre-hospital Victim Decontamination Topic Collection
- CDC: How to Self-Decontaminate After a Radiation Emergency
- HHS REMM: Decontamination Procedures
- OSHA: Hazardous Waste and Decontamination

Healthcare Response - Triage and Monitoring

There are many locations following a radiological or nuclear incident where patient care and victim assessment may take place, including casualty collection points, healthcare facilities, alternate care sites, community reception centers, and assembly centers.

- Casualty collection points or Rapid Triage and Treatment (RTR) points are spontaneously established and intended for primary assessment of injuries and triage to hospitals or alternate care sites.
- Healthcare facilities may be damaged or overwhelmed. The closer they are to the incident, the worse the situation is likely to be.
- Alternate care sites may be spontaneous or planned locations that act as overflow for healthcare facilities and provide patient care.
- **Community reception centers (CRC)** are designed for formal screening, decontamination, registration, assessment of potential internal and external contamination, and sample collection for bioassays. They require significant resources

and are *not* established in close proximity to a nuclear detonation event but must be established in nearby communities where resources are sufficient.

- **Assembly centers** are intended for rapid, qualitative screening of large numbers of uninjured persons that were in a fallout or prompt radiation exposure area after a nuclear detonation. They are assessed for symptoms of ARS and prioritized for cytokines and evacuation. These centers should be located near the margins of the dangerous fallout zone (DFZ) and opened around the time the 24-hour sheltering orders expire.

The functions of these centers are described in detail in a white paper titled *Population-Based Triage, Treatment, and Evacuation Functions Following a Nuclear Detonation*. Screening tools such as the "EAST- Exposure and Symptom Triage" tool may facilitate categorization of a large number of persons. Table 2 illustrates the difference between CRCs and Assembly Centers.

Table 2. Assembly Centers and Community Reception Centers

	Assembly Center (AC)	**Community Reception Center (CRC)**
Incident Type	Nuclear detonation	All community exposure events (RDD, power plant, nuclear)
Location	Close to detonation	Far from detonation
Resources in community	Scarce	Adequate
Goal	Rapid assessment for triage after total body radiation exposure	Detailed assessment for external and internal residual radiation
Resources required	Minimal	Extensive
Decontamination	Gross / Containment	Technical
Registration / interview	Minimal	Detailed
Other functions on site?	Likely – some medical care, cytokine administration, possible shelter / support operations	Unlikely

The RTR system provides a comprehensive schema for local planners to establish ad hoc sites, assembly centers, and coordinate transport to medical centers/hospitals and definitive care via evacuation centers.

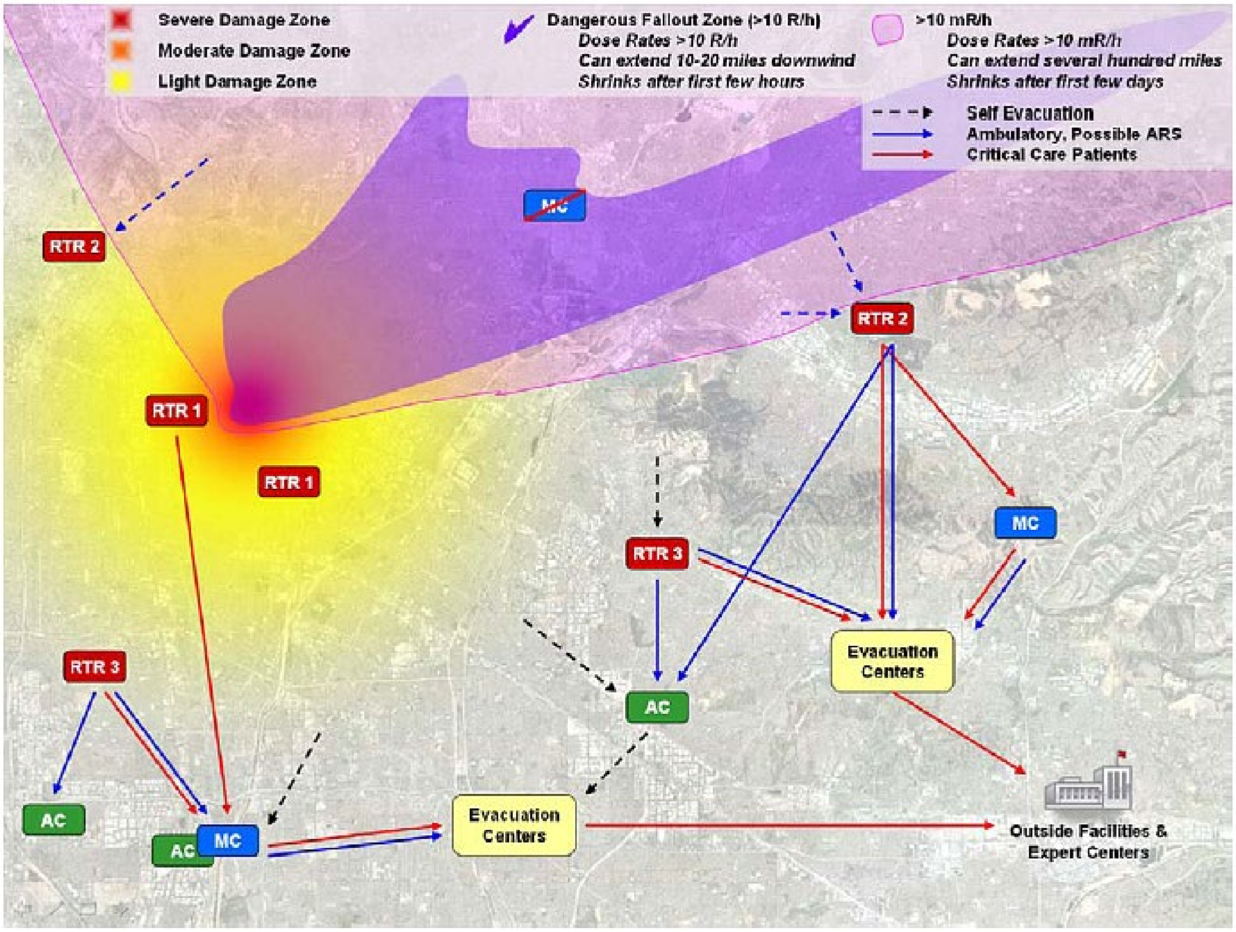

Figure 1. RTR System drawing from HHS REMM

Community Reception Centers

As mentioned above, formal CRCs do not appear on this figure as they are locations that would be established by public health, healthcare, and other response partners to provide radiation contamination assessment of uninjured evacuees after a radiological incident in areas where adequate resources exist. The use of this term may vary among the CDC and the local communities. This discrepancy is unfortunate but should be addressed by planners and incident managers to prevent confusion. Terminology and function can also vary among centers established for nuclear power plant incidents.

CRCs are located *outside* of the affected area. The CRC is primarily designed to assess contamination and *not* acute radiation syndrome. Their function is extremely important after non-nuclear radiation events such as a RDD to prevent severe strain on emergency services. Basic CRC services include:

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- Quantitative screening for external radioactive contamination
- Decontamination
- Assessment for need for bioassay and other testing to evaluate internal contamination
- Registering people for long-term follow-up and collecting epidemiologic information
- Prioritizing future testing and other steps for the individual

The CDC shares guidance for CRCs in the document Population Monitoring in Radiation Emergencies. CRC SimPLER is a CDC tool that helps estimate throughput capacity, staffing needs, and anticipates potential challenges during an emergency response.

Healthcare Response - Radiation Countermeasures

There are a number of countermeasures and pharmaceuticals available in limited quantities for radiation injury or internal contamination treatment that are discussed at length on the HHS REMM site. For the purposes of this document, the most commonly available and prescribed countermeasures are discussed in the following sections. Medical physicists and/or clinicians with access to the proper detectors or laboratories will provide the information needed. Using the wrong countermeasure can be harmful and/or waste time and resources. Clinicians must also manage symptoms caused by exposure in addition to considering countermeasure administration.

Cytokines (Neupogen, Neulasta, Leukine)

Cytokines are unique among the radiation countermeasures in that they help mitigate the effects of radiation injury to the bone marrow, if received in a timely manner. The purpose of administering these medications is to stimulate white blood cell and bone marrow growth, shortening the duration of severe neutropenia (decreased neutrophils, a type of white blood cell that is important to infection defense); minimize risk of complications (e.g., infections); and improve survival rates in patients exposed to radiation levels above 2 Gy/200 rad over an extensive portion of their body. Neupogen and other cytokines are administered by injection with complete blood counts needed every few days to monitor effectiveness.

After a nuclear detonation, HHS REMM's Interactive Scarce Resources Tool can be helpful for cytokine triage when there are more patients than medications, staff, or beds available. For maximum effectiveness the cytokines should be given within the first few days after exposure. Beyond 48 hours they are not as useful but may still help prevent complications.

For More Information:

- CDC: Neupogen
- FDA Approves Leukine for Acute Radiation Syndrome
- HHS REMM: Myeloid Cytokines
- Radiological and Nuclear Emergency Preparedness Information from FDA

The countermeasures listed next are used after an RDD or other incident when internal contamination of a single isotope is the dominant exposure risk. They are not typically needed or helpful after a nuclear detonation when total body irradiation is the primary source of exposure and ingestion/inhalation of isotopes is a relatively minor contributor. A nuclear detonation and many power plant incidents result in a variety of released isotopes, most of which have no specific countermeasure.

Most countermeasures act as a “sponge” to bind a specific radioactive isotope and remove it from the body but they are not an antidote to the isotope’s effects. Clinicians must match the suspected isotope to the correct countermeasure in order for there to be a clinical benefit.

DTPA

Diethylenetriamine pentaacetate (DTPA) is a medication that can bind to radioactive plutonium, americium, and curium to diminish the amount of time the elements stay in the body and facilitate their elimination in the urine.

The medication must be administered intravenously, or there is an inhaled form that can be administered if the radiation was inhaled. DTPA can only be administered under the supervision of a doctor or qualified medical professional. As with most countermeasures, it is most effective when administered immediately after exposure, preferably within 24 hours. Regular collection of blood, urine, and stool samples aid in the determination of DTPA effectiveness, so patients must remain either in a treatment location or return for regular care. Some states have caches of DTPA, and additional courses are available from federal resources.

For More Information:

- CDC: DTPA
- HHS REMM: DTPA
- Oak Ridge Institute: Radiation Countermeasures

Potassium Iodide (KI)

KI is only useful during nuclear power plant incidents. KI can help block radioactive iodine from being absorbed by the thyroid gland, which is susceptible to damage. KI cannot prevent radioactive iodine from entering the body or reverse its effects, therefore it is critical that KI is taken prior to, or very soon after, exposure. KI can be preemptively issued by communities to residents living or working within a 10-mile Emergency Planning Zone (EPZ) of a nuclear power plant. Depending on state plans, residents may have the pills in their possession to take prophylactically upon the direction of local emergency management or public health officials should an emergency occur at the power plant. There may instead be a process in place to distribute KI emergently. KI can be purchased without a prescription or dispensed after an incident, but the effectiveness would be limited.

Taking KI prior to exposure, or early into an ongoing exposure, serves to “fill up” iodine receptors in the thyroid with the “stable” iodine, so that when radioactive iodine passes through the thyroid, it is already unable to absorb the radioactive element.

KI is *only* effective in blocking effects of radioactive iodine on thyroid tissue. Though radioactive iodine can be released during a nuclear reactor incident, it is rarely the only radioactive isotope released. KI has no effect on other radioisotopes and has limited efficacy in adults as the thyroid does not take up iodine as readily and the long-term risk of cancer is much lower.

For More Information:

- [CDC: Potassium Iodine]
- [HHS REMM: Potassium Iodide]

Prussian Blue

Prussian blue is a capsule that binds to radioactive cesium and thallium to enhance elimination from the body. It binds to these elements in the intestines and is then excreted in bowel movements. Due to the physiology of intestinal fluids, Prussian blue is able to pull cesium and thallium circulating in the blood into the bowel and enhance excretion. It is best started as soon as internal contamination is confirmed but starting later is still useful, unlike KI.

Prussian blue is administered in pill form. If a patient is unable to swallow, the capsules can be broken and the contents mixed with food or liquid, however it will turn the patient's mouth and teeth blue. Feces may become blue during treatment, which generally lasts about 30 days, depending on regular bioassays that help determine efficacy. Staining can also affect growing teeth so use in children should be done carefully considered.

For More Information:

- [CDC: Prussian Blue]
- [HHS REMM: Prussian Blue]

Medical Surge

Besides the radiation effects, there are other injuries that can create a surge of patients seeking medical care. These include:

- Blast-related injuries
- Burns
- Respiratory irritation
- Eye irritation/injury from flash burns, flying debris, and dust/debris
- Acute mental health issues
- Concern for contamination/exposure

It is important to recognize after a nuclear detonation that there will be many people with physical trauma and little or no radiation exposure and people in the dangerous fallout zone with no physical trauma but with severe radiation exposure. Many people will be concerned about radiation exposure well beyond the at-risk areas. The burden on healthcare systems will be complicated after a nuclear detonation by infrastructure loss (including communications), access issues, and movement restrictions (e.g., road closures). Additional effects on the healthcare system are described in [this article].

> There will be many people with physical trauma and little or no radiation exposure and people in the dangerous fallout zone with no physical trauma but with radiation exposure.

The entire healthcare system, from 9-1-1 dispatch to definitive care, should be prepared to handle an initial dramatic surge in trauma patients and then an increase over the next few days, post-incident, in patients with a wide range of chief complaints including radiation-related vomiting and other symptoms. Many patients seen in the days and weeks following an incident will have exacerbation of underlying diseases due to disruptions to their normal care routine or environment. Later, patients may experience infections from wounds or from the effects of radiation illness.

After a nuclear detonation, many residents will self-evacuate and will present for assessment and care at hospitals hundreds of miles from the detonation site. There should be a process in place to refer asymptomatic patients to CRCs or other intake locations.

State, local, and federal staff should be prepared to support requests for staff and medical service delivery augmentation for this incident-related surge of patients.

Large-scale patient movement activities may take up to 72 hours to start and may continue for many days to weeks as patients are moved to Radiation Injury Treatment Network (RITN) hospitals and metropolitan areas for additional assessment and care.

Crisis Standards of Care (CSC) and Triage

What are Crisis Standards of Care/ Allocation of Scarce Resources?

Crisis Standards of Care (CSC) is defined as a substantial change in usual healthcare operations and the level of care it is possible to deliver, which is made necessary by a pervasive (e.g., pandemic influenza) or catastrophic (e.g., earthquake, nuclear) disaster. This change in the level of care delivered is justified by specific circumstances and cannot be mitigated by moving patients or resources rapidly enough to avoid triage/rationing decisions. (IOM, 2012)

What do I Need to Know?

Medical care that is rendered during a mass casualty incident occurs across three phases on a continuum (conventional care, contingency care, crisis care):

Table 3. Three Phases of Medical Care Rendered During an MCI

Incident demand / resource imbalance increases → Risk of morbidity / mortality to patient increases ← Recovery			
	Conventional	**Contingency**	**Crisis**
Space	Usual patient care space fully utilized	Patient care areas re-purposed (PACU, monitored units for ICU-level care)	Facility damaged / unsafe or non-patient care areas (classrooms, etc.) used for patient care
Staff	Usual staff called in and utilized	Staff extension (brief deferrals of non-emergent service, supervision of broader group of patients, change in responsibilities, documentation, etc.)	Trained staff unavailable or unable to adequately care for volume of patients even with extension techniques
Supplies	Cached and usual supplies used	Conservation, adaptation, and substitution of supplies with occasional re-use of select supplies	Critical supplies lacking, possible re-allocation of life-sustaining resources
Standard of Care	Usual care	Functionally equivalent care	Crisis standards of care
Normal Operating Conditions Conditions			Extreme Operating

The objective of mass casualty response is to remain in the conventional and contingency phases of response or to return to them as quickly as possible by effective management of resources.

Four resource categories are the key to successful hospital surge capacity implementation. Emergency physicians should understand the resources available in these areas and how additional resources or assistance may be obtained:

1. **Space:** adequate physical space to care for patients. This includes categories of space such as critical care, medical/surgical, and pediatric but also includes the availability of adequate outpatient space. Emergency providers should understand the expansion/surge plans for their department and region, including triaging of patients to

other locations or the opening of other clinical areas for emergency care.
2. **Staff:** sufficient, appropriately educated, and trained staff, including subspecialty staff. This includes the ability to call in or re-assign qualified staff and extend the capacity of current staff (e.g., by changing operational expectations during an incident, such as charting, patient ratios, and responsibilities).
3. **Supplies:** sufficient pharmaceuticals and medical supplies and equipment to provide care for the arriving patients. Availability of supplies varies greatly, depending on the size of the facility, its level of preparedness planning, and its role in the community (children's hospital, trauma center, Veterans Administration facility, etc.).
4. **Special:** considerations for specific incidents or populations outside of the usual clinical resources (radiation detection equipment, radiation safety officers / health physicist consultation, countermeasures, decontamination equipment).

In general, clinical resource shortages can be anticipated to occur in the following areas; strategies should be put in place in advance to curb the need for or length of CSC:

- Oxygen
- Medications (particularly antibiotics, cytokines, anti-emetics, and analgesia)
- Hemodynamic support (including intravenous fluids)
- Staff (EMS, medical, and nursing in particular)
- Blood products (unlikely to be in national shortage, aside from platelets in the weeks after a nuclear detonation, but institutional and regional shortfalls may exist for brief periods)
- Trauma care equipment and supplies
- PPE

This cardset from the Minnesota Healthcare System Preparedness Program and this ASPR TRACIE Crisis Standards of Care Topic Collection provide additional CSC resources.

Triage

An ethical framework must ground all disaster triage decisions. Core components of ethical decision making include the following:

- **Fairness:** The process is inherently just to all individuals, and the process itself treats all individuals equally who have needs.
- **Duty to care**: Physicians have a duty to care as best they can for all victims of an incident.
- **Duty to steward resources:** Physicians have a duty to attempt to obtain the best outcome for the greatest number of patients with the resources available (this does not specifically translate to "save the most lives" because a comfortable death may be a good outcome and thus appropriate to receive resources).
- **Transparency:** Though difficult in dynamic triage decisions, the process and criteria should be as transparent as possible.
- **Consistency:** The process should be applied in the same way to all presenting for care.

- **Proportionality:** The degree of resource restriction should be proportional to the demands.
- **Accountability:** Triage officers and others should be able to defend their decisions and be accountable for them. This may involve documentation and potential review of decisions by the institution and possible outside agencies.

For radiological events, the Proposed "Exposure and Symptom Triage" (EAST) Tool, used to assess radiation exposure after a nuclear detonation, is helpful in assessing likelihood of benefit.

In general, triage is guided by the principles of time, treater, and treatment – how much time is required, how much expertise by the "treaters," and how many treatment resources are available. The larger the disaster, the more medical efforts should focus on those with **moderate injuries**, where small interventions can have major impact on outcomes.

Combined injury (when radiation and trauma injuries co-exist) dramatically increases mortality. Coleman et al developed a radiation and radiation + trauma triage framework that can be helpful in prioritizing patients for aggressive management following a nuclear detonation.

Scarce Resources- This triage module (available on REMM) provides users with access to the following bulleted information and to an online flowchart/decision tree for complex triage decisions after a nuclear detonation incident. The resources provide background information on triaging and medically managing patients in the early days following a nuclear detonation. The online triage tool also allows for data entry and customization of decision-making.

- Use triage tool online
- Download triage tool for use offline by downloading REMM
- Print triage tool cards (PDF - 664 KB)
    - Download Mobile REMM which includes "Scarce Resources Triage Tool"
    - Read Scarce Resources Triage Tool Disclaimer information

For More Information:

- Using the Model of Resource and Time-Based Triage (MORTT) to Guide Scarce Resource Allocation in the Aftermath of a Nuclear Detonation

Additional Immediate Considerations

In addition to clinical considerations, there are other emergency management and operational issues that must be addressed within the community and within the healthcare system in the aftermath of a radiological or nuclear incident.

Emergency Information and Risk Communication

As the incident evolves from warning to initial impact, then response, and into recovery, risk communication and messaging focus will shift. During a nuclear event, early sheltering orders are critical and can save tens of thousands of lives. Communication includes providing the public with information through verbal, written, or symbolic means. Clear, concise, and coordinated messages provided by trusted leaders before, during, and after an incident will help residents be better informed to make important health-related decisions and ensure their safety. Messages should be accessible in multiple languages and media types, including social media and at the community level (e.g., churches, community centers, and other similar gathering places). Pre-scripted messages may be helpful, particularly for immediate shelter-in-place orders that communicate the need to seek shelter in as robust a structure as possible and as deep within the structure as possible.

Personal preparedness is critical for population survival and traditional means of communicating emergency messages may fail after an incident, so informing the public in advance about protective actions they can take, including best practices such as sheltering in place for at least 24 hours following a nuclear detonation and home decontamination, is vital. Other aspects, such as turning away immediately from any large flash (to avoid the incoming blast wave) and shutting down building ventilation systems in debris / fallout areas may also be included in pre-event education.

For more information:

- CDC Radiation Communication and Media Tools
- CDC Radiological Communications and Public Information
- CDC Radiation Hazard Scale: Communication Tool
- FEMA: Improvised Nuclear Device Response and Recovery- Communicating in the Immediate Aftermath
- Protective Action Guide (PAG) Public Communication Resources for a Radiological Emergency

Family Reunification and Patient Tracking

Following a radiological or nuclear incident, friends and family can be separated from each other and reuniting them is a priority for healthcare facilities, public health officials, and emergency managers. Establishing a coordinated approach for using social media, accessing search and rescue data, shelter rosters, and healthcare facility information is key to reuniting those affected by the disaster. Reunification may be complicated by information systems failures and impaired mobility of the population due to infrastructure damage and/or the need to shelter.

For more information:

- ASPR TRACIE Family Reunification and Support and Patient Movement and Tracking Topic Collections

Health Information Management

During a disaster, patients may be separated from their “medical home” and medical records. Information technology systems may be damaged in the incident and access to the systems may be limited by physical barriers, access issues, power disruptions, or other impacts. Patients being evacuated, or moved from one healthcare facility to another, need to have access to their medical records, but that is not always possible if the facility has experienced significant damage, paper records are missing/compromised, or electronic records are not accessible.

Redundant IT systems and back-up paper records with critical information are a few ways to mitigate post-disaster health information issues. To find more best practices for downtime procedures, review the ASPR TRACIE Healthcare System Cybersecurity Readiness and Response Considerations resource, including the Appendix and corresponding downtime preparedness and downtime operations checklists.

There is no current national system that can be used as a radiation injury registry or to track cytokine administration or other interventions. Jurisdictions should plan to have basic paper-based tracking systems in place and give an information card to the patient with treatment information and further instructions.

For More Information:

- ASPR TRACIE Communications Systems Topic Collection
- ASPR TRACIE HIPAA and Disasters: What Emergency Professionals Need to Know
- ASPR TRACIE Information Sharing Topic Collection
- CDC Communication and Public Information in Radiation Disasters

Pediatric Concerns

Children comprise nearly one quarter of the US population, meaning there are approximately 74 million children under the age of 18, living in the U.S. today. Children have different physiology and medical needs that make them more vulnerable to certain injuries and require special equipment and training to manage. They are also more easily affected by changes in a post-disaster environment (such as temperature and air quality) and daily routines (such as school closures or loss of permanent housing). Children are often disproportionately impacted in disasters, which can place a strain on local communities, whose pediatric resources are likely limited. Their needs are often overlooked and misunderstood so that special planning must be done within communities to ensure these issues are adequately addressed.

In addition, screening and decontamination efforts may be frightening. Children also may be orphaned or separated from parents necessitating a pediatric safe area for observation until a caregiver is located.

Due to the differences in lifespan, similar radiation doses in children confer a higher risk of long-term mortality from malignancy than in adults. The American Academy of Pediatrics reviews specific risk factors that make children more susceptible to injury from the effects of radiological emergencies. AAP resources highlight the following considerations:

- Children have a greater body surface area to weight ratio than adults and skin that is more permeable, rendering them more vulnerable to thermal and radiation burns.
- Young children cannot shield their eyes making them more susceptible to ocular injuries.
- Children’s respiratory rate is higher than adults and they breathe air lower to the ground, making them more susceptible to particulate radiation exposure.
- Children are more susceptible to volume loss from gastrointestinal compromise in ARS.
- Children will be more vulnerable to psychological trauma during a disaster or emergency incident.

For more information:

- AHRQ: Pediatric Terrorism and Disaster Preparedness
- American Academy of Pediatrics:
    - Chemical-Biological Terrorism and Its Impact on Children
    - Radiation Disasters in Children
- HHS REMM: At-Risk/ Special Needs Populations – Infants and Children

Regulatory Concerns

Healthcare facilities in areas affected by radiologic incidents may be forced to function outside their normal operating conditions, particularly after nuclear detonation. This situation could include a surge of patients requiring the healthcare facility to implement mass casualty protocols, crisis standards of care, or defer patients seeking screening or evaluation that do not have acute or life-threating symptoms. It could also include impacts that cause the facility to be inoperable forcing evacuation and potential closure. The following resources provide information on disaster declarations and waivers in disasters related to healthcare entities.

For more information:

- ASPR TRACIE Healthcare-Related Disaster Legal/Regulatory/Federal Policy Topic Collection
- EMTALA and Disasters

Handling Contaminated Medical Waste

A radiological incident may generate a large amount of contaminated materials at the hospital including contaminated clothing and medical supplies. Healthcare facilities should discuss contingency planning and surge plans with their current medical waste vendors as well as determine plans for radiologic waste. Police, fire, and EMS stations, hospitals, and other healthcare facilities should be prepared for people to bring hazardous waste, such as contaminated bagged clothing, to the facilities for disposal if they do not know or are not told what to do with it.

Emergency management will need to determine a process for screening clothing. This could occur at the CRC or other locations. Thresholds will need to be set for release of clothing to the patient vs. destruction of clothing. Communications and logistics must be addressed to assure that salvageable clothing is washed appropriately, and a system is in place to return belongings to individuals.

For more information:

- Management of Radioactive Waste from the Use of Radionuclides in Medicine
- Radioactive Waste Disposal Fact Sheet

Ongoing Considerations

(in alphabetical order)

Exacerbation of Chronic Medical Conditions

- Any chronic medical condition can be exacerbated in a disaster due to the stress of the incident, movement/evacuation of the patient to a different location, loss of utilities, lack of access to medications, and/or loss of access to equipment or devices needed to support daily medical care. In particular, the following patients become highly vulnerable: Dialysis Patients
- Patients dependent on medical devices that require electricity (e.g., oxygen concentrators, ventilators, and home dialysis systems).
- Patients who are receiving hospice care.
- Patients whose conditions must be continually managed by prescription medications (e.g., seizure disorders, diabetes).
- Patients with mental health diagnoses and/or alcohol or drug dependencies.

Such at-risk patients will need access to healthcare facilities and services; chronic or maintenance medications or therapies; and operational medical equipment in order to maintain their pre-disaster health conditions and not become an additional burden on the healthcare system.

The emPOWER program can identify Medicare patients who are dependent on durable medical equipment and other vulnerable diagnosis codes in order to target post emergency support. The data includes information on beneficiary claims for ventilator, BiPAP, internal feeding, IV infusion pump, suction pump, at-home dialysis, electric wheelchair, and electric bed equipment within the past 13 months; oxygen concentrator equipment in the past 36 months; and an implanted cardiac device (i.e., LVAD, RVAD, BIVAD, TAH) within the past 5 years. Ideally, this information is made available as part of a pre-event planning operation, but just-in-time coordination with the emPOWER program is also possible.

The Emergency Prescription Assistance Program (EPAP) is a potential resource available for affected areas to support access to prescription medications. In addition, national pharmacy chains have mobile pharmacy units available to deploy within local communities. Rx Open, managed by Healthcare Ready helps patients find nearby open pharmacies in impacted areas.

Additional information on EPAP and historical use from past activations can be found on ASPR TRACIE:

- EPAP Overview Fact Sheet
- EPAP Louisiana Floods
- EPAP Hurricane Ike
- EPAP Hurricane Gustav
- EPAP Superstorm Sandy

Extended Loss of Power

Healthcare facilities must have power in order to continue operations. Rapid needs assessment of healthcare and residential care facilities, and supplementation with external generators will be critical to preventing evacuation and ensuring continued operation. If areas face loss of power for extended periods of time, residents with chronic medical conditions may experience exacerbated symptoms, people can become sick from spoiled food, and medications that need to be refrigerated can lose potency or spoil.

Aerial detonation of a nuclear device can theoretically generate an electromagnetic pulse (EMP) strong enough to damage the electrical grid, and damage individual electronic equipment. If this were to occur, even if a generator was available, it may not work, and electronic equipment may not be functional. Devices may be unusable or may need a "re-boot". While there are differing opinions on the potential impact of an EMP, most experts agree that effects from a ground burst detonation would likely be negligible beyond the zone of moderate damage.

For More Information:

- ASPR TRACIE Topic Collections:
  - Continuity of Operations (COOP)/ Failure Plan
  - Utility Failures
- EMP Resources:
  - Assessing the Risk of Catastrophic Cyber Attack: Lessons from the Electromagnetic Pulse Commission
  - Electromagnetic Pulse (EMP), Part I: Effects on Field Medical Equipment
- Planning for Power Outages: A Guide for Hospitals and Healthcare Facilities

Fatality Management

Radiological and nuclear incidents have the potential to cause mass fatalities with contaminated decedents and present challenges to death scene investigations, safe handling, decontamination, patient identification, decedent transport and storage, and notification of family. Fatality management resources may also be limited due to the size of the incident.

For More Information:

- CDC Guidelines for Handling Decedents Contaminated with Radioactive Materials
- HHS REMM: Management of the Deceased
- Model Procedure for Medical Examiner/Coroner on the Handling of a Body/Human Remains that are Potentially Radiologically Contaminated
- Planning for Power Outages: A Guide for Hospitals and Healthcare Facilities

Healthcare Facility Evacuations and Sheltering in Place

Healthcare facilities in the immediate area of a radiological or nuclear incident will likely be asked to shelter in place, or they may also be asked to evacuate after the immediate impact if the location or the facility is deemed unsafe. The risks of a healthcare facility evacuation or shelter in place decision must be balanced, and weighed against the regional capacity to transport, track, and accommodate patients amid a radiological or nuclear disaster. Facilities should prepare in advance for both possibilities and understand that evacuation may be delayed or impossible due to difficulty reaching the facility, as well as competing community needs that EMS and other agencies will have. Hospitals should also plan for the need to shut down air handling systems to prevent contamination inside the facility.

In some cases, residual contamination may be present outside the facility with very low levels inside. Staff may need reassurance that it is safe to travel to or leave the facility. For example, radiation levels around Fukishima Medical Center were above the 10mrem/h usual threshold for days after the reactor meltdowns but levels inside the buildings were trivial due to their concrete and metal construction.

Healthcare coalitions and health systems can be excellent resources in making regional decisions and supporting evacuation operations.

For More Information:

- ASPR TRACIE Topic Collections:
  - Healthcare Facility Evacuation/Sheltering
  - Patient Movement and Tracking
  - Pre-Hospital

Medical Services Replacement or Augmentation

Healthcare facilities could be damaged or destroyed by a nuclear incident, be forced to close due to plume (e.g., power plant, nuclear), contamination, loss of utilities, or other physical issues, and be "off-line" for an indefinite amount of time. Individual healthcare providers may be personally affected by the disaster and unable to report to work. Some may choose not to work during such an incident. Outpatient providers may not be able to open their offices/clinics because of lack of staff, physical damage, or loss of communications. In these cases, alternate care sites may be needed to provide additional capacity. After a nuclear detonation medical support may also be needed at Assembly Centers.

Replacement healthcare services for facilities that are temporarily unavailable or those that are permanently damaged will need to be coordinated including physical and virtual options (e.g. telemedicine). There will also be a need to augment existing healthcare facilities as they can see a surge of patients seeking routine care (non-disaster related) in new locations, due to a lack of available pre-disaster providers.

For More Information:

- ASPR TRACIE Topic Collections:
  - Alternate Care Sites
  - Ambulatory Care and Federally Qualified Health Centers (FQHC)
  - Crisis Standards of Care
  - Hospital Surge and Immediate Bed Availability
  - Pre-Hospital
  - Virtual Medical Care

Select Programs/Assets to Consider:

- State Medical Response Teams (Inter- or Intrastate)
- Emergency Management Assistance Compact

Shelter and Congregate Living Health and Health Concerns

Widespread structural damage and/or radiological contamination could create the need for large-scale shelter operations. While the goal for emergency management is to return people to their homes, or to provide transitional housing, radiation levels may preclude safe return home.

The shelter environment must be safe and shelter residents must have access to basic hygiene and healthcare services, clean water, security, and safe food.

Shelters will need to conduct radiation screening at their entrances in order to keep contamination to a minimum. Background levels of radiation will rise over time, and acceptable levels of contamination to enter the shelter will need to be determined and adjusted as needed. In Japan, a threshold of less than 20,000 to 100,000 cpm on a portal monitor was used to denote 'clean' for entry in many shelters after the Fukushima event. Over 440,000 persons were screened in four days. About 400,000 persons required shelter in the immediate aftermath and over 90,000 were still in shelters three months later.

Depending on how long people will reside in shelters, potential public health hazards must be monitored (e.g., food safety and hygiene [toilets and showers]). Ensure surveillance is in place to monitor for infectious disease outbreaks, specifically respiratory and gastrointestinal diseases.

People may bring pets to shelters, hospitals, or other alternate care sites. Coordination between health personnel and public health and emergency management partners will be necessary to manage pet needs. Pet radiation screening and decontamination services must be addressed in community radiation response plans.

Staff Fatigue, Replenishment, and Willingness

In the first few days of a response, staff will be focused on rescue and response operations and often can't or won't rest or remove themselves from operations. Staff who maintain facility operations are a critical component of the response phase in addition to clinical staff. Hospital staff are expected to care not only for their own loved ones, and their patients, but often community members as well. Fatigue, stress, and inadequate nutrition and hydration can lead to declining cognitive abilities, increased risk taking (e.g., failure to use protective equipment), and emotional distress and exhaustion. Reactions stemming from extended periods of stress can place both staff and patients at risk. Incident management should prioritize staffing plans that include adequate rest and replenishment cycles for their workforce.

In addition to health system partners, state and federal supplemental staff and Medical Reserve Corps volunteers can be sought to assist and support local healthcare assets.

Finding additional staff may be challenging during a radiation event due to the lack of understanding around risks to healthcare workers. Numerous studies on healthcare personnel's willingness to report to work during a disaster found staff are less willing to respond to a radiological event than a natural disaster. Suggested reasons include, perceived high personal health risk, lack of training/knowledge on risks and impacts, lower confidence in ability to perform ones' clinical role, and negative perceptions of hospital ability to protect staff.

Some ways to reduce staff anxiety, increase their sense of safety, and improve willingness to respond during such an event include: education on radiological risks (prior to the event and just-in-time); use of electronic dosimeters to demonstrate low levels of exposure; treatment and response training; implementation of clear and consistent risk communication; and demonstrable investment in staff safety precautions.

For more information:

- ASPR TRACIE Tips for Retaining and Caring for Staff in a Disaster
- Characterizing Hospital Workers' Willingness to Respond to a Radiological Event
- Factors Affecting Hospital-based Nurses' Willingness to Respond to a Radiation Emergency
- Willingness of Health Care Personnel to Work in a Disaster: An Integrative Review of the Literature

Transportation

After a nuclear detonation, EMS providers may have difficulty accessing patients due to debris and lack of communications systems and/or their fleet may suffer disaster-related damage. Residents may not be able to use traditional modes of transportation to access their healthcare providers or emergency services. Private vehicles may have been damaged or inaccessible (or immobilized in the street), buses may not be running, taxis and car services may not be operational, and paratransit, Handi-vans and other medical transportation providers may be otherwise committed to response operations or may lack staffing.

Roads may not be passable, so physical access to facilities for both ambulances and self-referred patients can be an issue. Other vehicles including buses, air medical transport, and military vehicles may be needed to transport the injured to functioning hospitals.

Many services that provide support to healthcare facilities will have access issues including courier services that handle lab specimens and delivery services that bring supplies, equipment, linen, food, fuel, and other necessary resources. These services and vendors may also have difficulty crossing security barriers into affected neighborhoods if they lack proper paperwork or identification.

RITN should be contacted for coordination and transportation of patients being referred to their facilities. Federal agencies will help provide ambulances and other transport platforms, particularly for evacuation of patients from the affected area.

Long-Term Considerations and Recovery

Change to the Baseline Level of Health

If regular and consistent access to healthcare is impeded due to the impact of a radiological incident, or if widespread radiation contamination occurs, the overall health of a community can be impacted. If the healthier members of the community choose to relocate, leaving behind those with pre-existing conditions and a lack of resources, the baseline health of the community can be affected but with disproportionate effects on those with chronic conditions and those with access and functional needs. During recovery, efforts to ensure continuity of services for these populations is critical to health maintenance. Radiation exposure registries may be established to track the long-term health effects of persons with significant radiation exposure.

Contaminated Areas (Permanent and Temporary)

Depending on the incident type and severity, there may be areas and buildings that cannot be occupied either in the short-term or long-term. The community will need to assess what assets and facilities are affected by this contamination and evaluate where needed healthcare services should be re-located.

For context, following the 2011 nuclear incident at the Fukushima Daiichi nuclear power plant, officials issued evacuation orders that extended 20 kilometers (about 12 miles) from the plant, in some areas more, due to plume pathways. As of September 2015, the government started lifting the orders for locations on the perimeter after conducting massive rehabilitation efforts including washing down buildings and structures, and the removal of 9 million cubic meters of soil. Many residents and business owners have yet to return because they have personally determined the risk is too high. This page, maintained by the Fukushima prefecture includes a map of the affected area with current radiation readings (7 years after the incident).

Loss of Facilities and Providers

Many of the healthcare facility closures or disruptions during, and immediately following, the incident could be temporary and normal operations could resume relatively quickly, but there will be facilities that will not be able to quickly or easily re-open if damage or contamination is widespread. In addition to the loss of healthcare facilities, the impacted area may also experience healthcare provider attrition. They may relocate due to radiation exclusion areas, their own personal losses or concerns, or may leave because there was no available work in the immediate aftermath due to facility damage or lower patient volumes. Providers who have moved, found a new job, or resettled may be reluctant to return to the impacted area once their previous facility is operational again.

Additional Radiation Resources

In addition to the clinical considerations discussed above, there are other emergency management and operational issues that must be addressed. The following resources can provide information to all emergency decision makers in a radiological or nuclear event.

Radiation Emergency Medical Management (REMM)

The U.S. Department of Health and Human Services (HHS) Radiation Emergency Medical Management (REMM) and the Centers for Disease Control and Prevention (CDC) Radiation Emergencies sites provide guidance for healthcare providers, primarily physicians, about clinical diagnosis and treatment of radiation injury and response issues. HHS REMM aims to provide just-in-time, evidence-based, usable information with sufficient background and context to make complex issues understandable to those without formal radiation medicine expertise. REMM is also downloadable to mobile platforms.

Recommended links from the HHS REMM site include:

- Radiation Basics: Learn the Basics, Contamination Vs. Exposure, Shielding, Measuring Radiation, Personal Protection
- Radiation Incidents: Discovering an Incident, Characterizing Severity, Timeline of an Incident, Incident Types, Nuclear Explosions, Public Messages
- First Responders: PPE, Initial Actions, Casualty Management, Triage in the Field, HazMat
- Planners: Federal Disaster Response Plans, National/State/Local Radiation-Specific Response Plans, Incident Command System, Incident Registry
- Patient Management: Initial Incident Activities
    - Triage Guidelines
    - Radiation Algorithms
    - On-Site Activities
    - Victim Transport
    - Hospital Orders Template
    - Hospital Activities
    - Medical Countermeasures

Centers for Disease Control and Prevention (CDC) Radiation Emergencies

Recommended links from the CDC Radiation Emergencies site include:

- Types of Radiation Emergencies: Nuclear, RDD, RED, Power Plant, Occupational
- Contamination vs. Exposure: Types of Contamination
- Information for Clinicians: Patient Management
- Medical Countermeasures: Internal Contamination, Radiation Exposure
- Possible Health Effects: Short-Term, Long-Term

Radiation Emergency Assistance Center/Training Site (REAC/TS)

The Radiation Emergency Assistance Center/Training Site (REAC/TS) is a world-renowned, U.S. Department of Energy (DOE) asset and a leader in emergency medical response to radiological/nuclear incidents, providing emergency response, advice, and consultation for the National Nuclear Security Administration's (NNSA) Office of Counterterrorism and Counterproliferation. REAC/TS is located at the Oak Ridge Institute for Science and Education in Tennessee and is operated for DOE by ORAU.

Subject matter experts at REAC/TS are on-call and ready to deploy (as well as available for phone advice and consultation) 24/7 in support of DOE/NNSA and may provide direct support to the DOE/NNSA Federal Radiological Monitoring and Assessment Center.

REAC/TS supports the international community as a Pan American Health Organization (PAHO)/World Health Organization (WHO) Collaborating Center for radiation emergency management and participates in WHO Radiation Emergency Medical Preparedness and Assistance Network (REMPAN). As a DOE asset, REAC/TS is also an active member of the

International Atomic Energy Agency (IAEA) Radiation Assistance Network (RANET).

REAC/TS can be consulted by contacting the DOE Watch Office 24hr number: 202-586-8100 or the emergency number: 865-576-1005 (ask for REAC/TS).

For More Information:

- REAC/TS
- National Guard Civil Support Teams

Medical Radiobiology Advisory Team (MRAT)

The Medical Radiobiology Advisory Team (MRAT) is a deployable team responsible for providing expert advice to incident commanders and staff during a radiological incident. The MRAT is a two-person team, usually consisting of 1 health physicist and 1 physician, specializing in the health effects of radiation, biodosimetry, and treatment of radiation casualties.

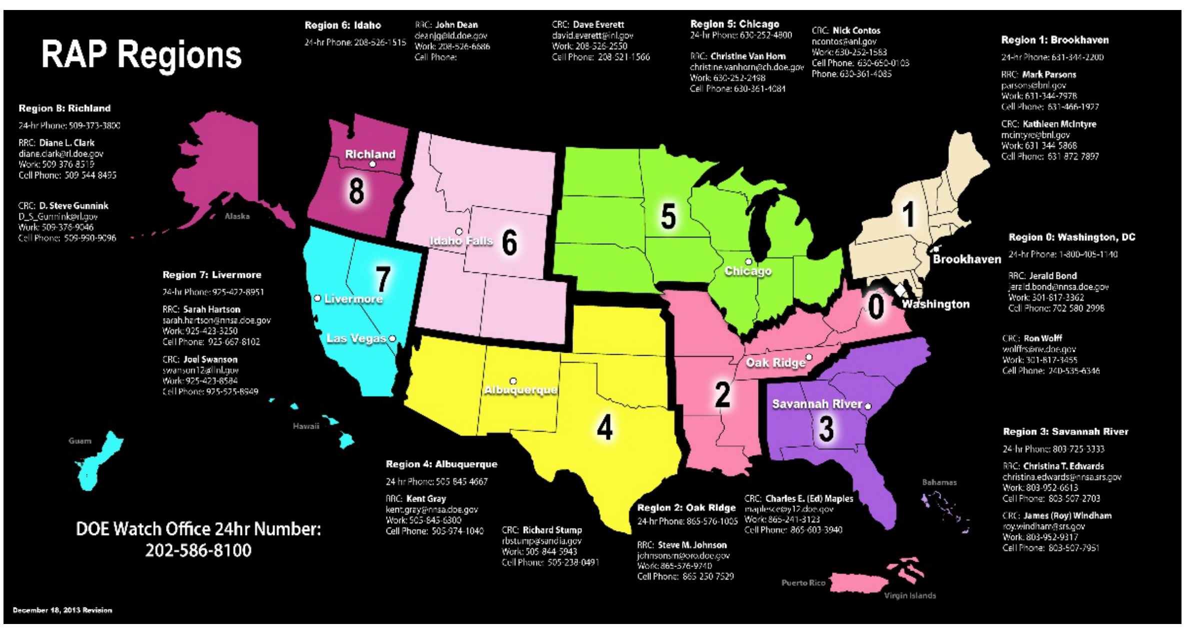
To contact the MRAT, please call the MMO Duty Officer at (301) 295-0989. You may also contact the AFRRI security desk at (301) 295-3038 and ask for the MRAT.

For More Information:

- Armed Forces Radiobiology Research Institute

Department of Energy Radiation Assistance Program (DOE RAP)

RAP provides radiological assistance for incidents involving radioactive materials that pose a threat to health and safety or the environment. RAP can provide field deployable teams of health physics professionals equipped to conduct radiological monitoring and assessment activities, and can be activated by notifying the DOE Watch Office 24hr number: 202-586-8100. The DOE also maintains operational readiness of the Federal Radiological Monitoring and Assessment Center (FRMAC).



TRACIE
HEALTHCARE EMERGENCY PREPAREDNESS
INFORMATION GATEWAY

For More Information:

- NNSA Nuclear Incident Response
- FRMAC

Medical Emergency Radiological Response Team, Veterans Administration

The Medical Emergency Radiological Response Team (MERRT) is a specially trained team of medical providers who can support federal, state, and local response to nuclear power plant incidents and other radiological or nuclear emergencies. They can be deployed to an off-site location to provide direct patient care and technical advice.

For more information:

- FEMA Interagency Modeling and Atmospheric Assessment Center

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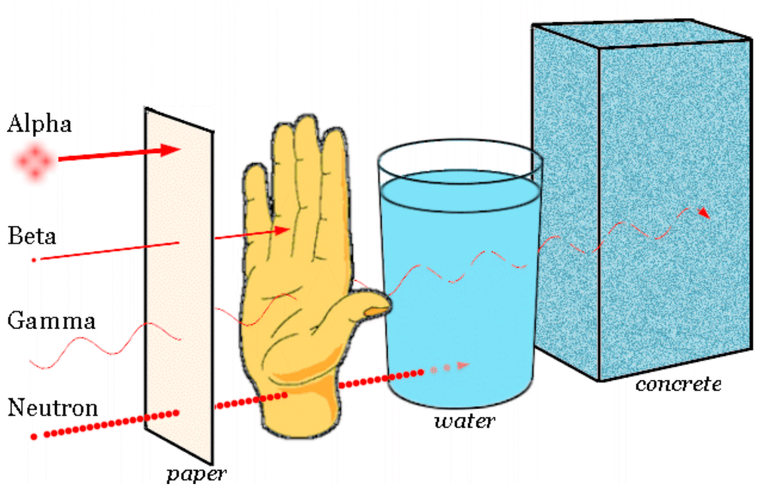
Appendix A: Radiation Terminology

Types of Radiation

There are four types of radiation: alpha, beta, neutron, and gamma. Many sources of radiation emit more than one type of radiation; some remit only one type.

Radiation Type	Components	Properties	Penetration	Health Effect	Detection	Common Isotopes
Alpha (α)	Two protons and two neutrons	Heaviest radiation particle and travels only a short range Can remain on skin causing contamination	Usually unable to penetrate skin, can't penetrate clothing, paper	Can be harmful if inhaled, swallowed or absorbed through open wounds	A thin-window Geiger-Mueller probe can detect the presence of alpha radiation, but usual survey instruments can't detect the presence of alpha radiation reliably since the rays cannot penetrate even dust	Alpha emitters include radium, radon, uranium, thorium (many also emit other types of radiation – few are pure alpha emitters)
Beta (β)	Electron not attached to an atom	Light, short range particle Can remain on skin causing contamination	Can travel several feet and can penetrate several layers of skin. Clothing can provide "some" protection	If beta particles are left on the skin they can cause skin injury (beta-burns) Can be harmful on direct skin contact, if inhaled, swallowed or absorbed through open wounds	Can be detected by many survey instruments and a thin-window Geiger-Mueller probe	Beta emitters include strontium-90, carbon-14 (used in carbon dating), hydrogen-3 (tritium), and sulfur-35
Neutron (n)	Present in the nucleus of an atom	Byproduct of nuclear fission and fusion as created by nuclear power plants and nuclear weapons Would NOT be present in RDD	Highly penetrating and can travel a great distance, but can be stopped by high volumes of water	Can be damaging to human tissue	Personal radiation detectors can detect gamma and/or neutron radiation Most handheld survey meters detect beta and gamma radiation, but some can detect all types.	
Gamma (γ)	High-energy photons, same electromagnetic spectrum as light (10,000 times as much energy as visible photons)	No mass and no electrical charge (therefore no contamination) Gamma rays frequently accompany alpha and beta radiation	Highly penetrating electromagnetic radiation – can easily penetrate most material, including human tissue and can travel thousands of meters in the air before expending their energy Dense material is needed for shielding such as several layers of lead lining or many feet of concrete	Can be damaging to human tissue to include the full range of acute and chronic radiation sequelae	Easily detected by instruments and probes with sodium iodide detector Gamma waves often pass through the body leaving no contaminant but causing significant injury (irradiation, not contamination) – patients exposed to gamma emitters need evaluation for both	Gamma emitters include iodine-131, cesium 137, cobalt-60, radium 226, and technetium-99m



Source: Photo courtesy of Baylor College of Medicine

For More Information:

- CDC Radiation and Your Health
- EPA Radiation Protection
- Health Physics Society: What Types of Radiation Are There?
- U.S Nuclear Regulatory Commission. What are the Different Types of Radiation?

Exposure and Dose

International scientists use the System Internationale (SI) derived from the metric system when referring to radiation measurement. Scientists in the United States use the conventional system of measurement, which can lead to the use of different terms for the same measurement.

The term used to measure the amount of radiation emitted from a radioactive source is either a **curie (Ci)** in conventional measurement or **becquerel (Bq)** in SI. One Ci is equal to 37 billion Bq.

The term used to measure the radiation dose absorbed by a person (energy deposited in human tissue) is either a **rad** in conventional measurement or a **gray (Gy)** (100 rad) in SI. This is the absorbed dose.

The risk of biological exposure or equivalent dose is measured in **rem** in conventional measurement or **Sievert (Sv)** (100 rem) in SI. This dose is a calculation of the absorbed dose multiplied by a converting factor based on the medical effects of the specific type of radiation as noted in Federal Guidance Report 12: External Exposure to Radionuclides in Air, Water, and Soil.

From an initial response standpoint, it is acceptable to consider rad and rem and Gy and Sv interchangeable when performing initial screening or establishing safety zones when the incident does not involve significant alpha contamination.

People can receive an external dose by being near radiation sources and an internal dose by inhaling or ingesting radioactive material. External exposure stops as soon as you leave the affected area or remove the external contamination. Internal exposure continues until the material is removed from the body.

Radionuclides also have different uptake and impacts for various organs. Internal dose can be calculated for each organ separately. Definitive radiation injury management under conventional conditions involves calculating the effective dose equivalent using a weighting system called the FGR 11 for each organ. Each organ's dose is multiplied by its weighting factor and the results are added together to calculate the effective dose equivalent which provides a risk for developing stochastic effects of radiation, such as cancer (CDC, 2018). Health physicists are critical to these calculations.

The distinction between *irradiation* and *contamination* and impact on screening is critical. Irradiation is when gamma waves or neutrons pass through the body – this can induce severe injury but leave no contamination at all for the survey instruments to pick up. Therefore, irradiation risk is all about location at the time of potential exposure and impact is assessed through Absolute Lymphocyte Counts and other data. Contamination, on the other hand, can result in impressive numbers of 'clicks' on the survey counters (counts per minute) but still represent trivial radiation exposure to the patient, depending on the level and type of radiation emitted, and the duration of exposure. It is important to consult radiation experts to assist in assessing the risks of radiation exposure and contamination specific to each particular incident.

For More Information:

- HHS REMM Radiation Units and Conversions
- CDC Measuring Radiation
- CDC Radiation Dictionary
- CDC Primer on Radiation Measurement
- Environmental Protection Agency Radiation Protection
- Health Physics Society

Dose Equivalencies/Comparisons

Sources of "Everyday" Radiation Exposures

The CDC provides common radiological exposures for comparison in their Radiation Thermometer.

Common Exposures

- Exposure to cosmic rays during a roundtrip airplane flight from New York to Los Angeles: 0.0035 rem/0.035 mSv
- One dental x-ray: 0.0005 rem/ 0.005 mSv
- One chest x-ray: 0.01 rem/ 0.1 mSv
- One CT scan: 1 rem/ 10 mSv
- One year of exposure to natural radiation (from soil, cosmic rays, etc.): 0.31 rem/ 3.1 mSv.

In radiation incidents, the following dose thresholds can be used for predictive purposes.

- Relocation Threshold (the point at which people should be relocated if it is expected that they will receive a dose, at or above this point, for the coming year): 2 rem/20 mGy
- Damage to blood cells: 50 rem/ 500 mGy
- Acute Radiation Syndrome/Increased Cancer risk: 100 rem/ 1000mSv/ 1 Gy
    - Lowest dose that could cause acute radiation syndrome
    - Dose for which risk of getting a fatal cancer increases from about 22% to 27%
- 50% Lethality with no medical interventions: 400 rem/ 4000 mSv / 4 Gy
- 100% Lethality: 1000 rem/ 10000mSv / 10 Gy

The EPA states that environmental exposure of more than 75 rad/ 0.75 Gy in a short time is the minimum amount to cause acute health effects. Exposures between 5 and 10 rad/ 0.05 - 0.10 Gy usually result in no health effects.

Responder thresholds:
These thresholds are typically established for the incident by the incident commander or radiation authorities.

- Emergency responders should try to keep doses below 5 rad
- In life-saving situations, responders may go up to 25 rad or more depending on the relative risks to responders and victims

Radiation exposure is reduced by:

- Time – limiting the time of exposure
- Distance – radiation decreases with increase in distance from the radiation source. For every doubling of distance away from the sources, the radiation exposure decreases to one-fourth of the exposure rate at the previous location (double the distance is one fourth the dose) therefore, even very small amounts of distance between the person and the source can result in dramatic reductions in the level of exposure
- Shielding – when possible, using shielding to block the radiation – easy for alpha and beta, not easy for gamma or neutrons (though x-rays are stopped by thin lead shields, these have little effect on most gamma rays). Shielding is also not as effective in a contamination field where there is not a single source of radiation, but many sources.

Radioactive Isotopes and Byproducts

Accepted Half-Lives of Commonly Used Radioisotopes chart lists all radioactive isotopes with greater than 100 year half-life. An element decays to undetectable levels within 10-15 half-lives (6 half-lives is good estimate)

The HHS REMM lists isotopes of interest including properties, treatment, and fact sheets.

Radiation Detection

The HHS REMM site provides a description of numerous radiation detection devices and describes the proper situations to use them. This section describes of a selection of devices that are commonly available to first responders and screening personnel. There are also portal detectors (for screening people or vehicles), fixed detectors, radionuclide identifiers, dose rate meters, and other devices. The choice of detector depends on both the goal of use and user training/experience. Planners should be familiar with what assets exist in their area and how they are to be used. Remember, none detect radiation injury from *irradiation* that occurred from gamma waves that passed through the patient, so they are not a screen for radiation injury – only contamination. Most units do not detect alpha particles well and have variable sensitivity for beta.

Geiger Counter

A Geiger counter is the classic device used to detect levels of radiation in the environment or on a person. They often use a pancake probe attached to a main unit. They do not specify the isotope, only the number of ion pairs created in the instrument chamber per minute which reflects emission activity. If the speaker is turned on, you can hear the clicks/counts per minute and it usually has a needle on a scale (dependent on the unit, it may be counts/minute (CPM), mR/h, etc.) Sporadic clicks represent normal background radiation and for persons getting screened, an impressive number of clicks still usually represents low level contamination. Many meters have scale switches/knobs so it is important to use a setting that keeps the needle within the scale range (usually screening is conducted with the knob in the most sensitive position and adjusted to a readable scale when higher counts 'peg' the needle on the right side of the gauge.

Hospitals should work with their radiation safety officer and nuclear medicine department (if the facility has one) on their radiation response plans. These personnel will generally be more familiar with radiation safety processes, screening, and use of survey equipment.

Personal Dosimeters

Personal dosimeters are small radiation monitoring devices typically worn by people working in environments where exposure to radiation is possible, such as medical radiology staff, first responders, or staff that operate in a nuclear power plant. There is a huge variation in type and reliability of personal dosimeters on the market. Some detect extremely low-level exposures, some require significant exposure to register, some provide real-time alerts to exposure (e.g. digital dose-rate meters), while others are worn for a scheduled period of time and then submitted for evaluation on a routine basis (e.g. film badges).

RadNet

Different from a hand-held or personal device, RadNet is a nationwide environmental radiation monitoring program managed by the Environmental Protection Agency (EPA). RadNet has more than 130 radiation air monitors in 50 states, monitoring 24/7 for gamma radiation. By running constantly, the system is able to determine the "normal", background level of radiation and can detect spikes or surges in near real time. For selected special events, mobile monitors may be deployed at ground level or via airborne surveys to provide early potential warning of ground-based terrorist attacks.

For More Information:

- EPA RadNet
- Medical Isotopes: General Concepts
- REMM Radiation Detection Devices
- FRMAC
- IMAAC
- NNSA Nuclear Incident Response

Appendix B: Additional and Cited Resources

In addition to HHS REMM and CDC, the following resources are recommended by members of the ASPR TRACIE Subject Matter Expert Cadre as important reference documents for radiation emergency information:

Suggested Quick Links for Radiation and Nuclear Emergency Information

- A Decision Makers Guide: Medical Planning and Response for a Nuclear Detonation
- Medical Aspects of Radiation Incidents
- Medical Planning and Response Manual for a Nuclear Detonation Incident
- National Alliance for Radiation Readiness (NARR)
- Nuclear Radiological Incident Annex
- Planning Guidance for Response to a Nuclear Detonation
- Radiological Terrorism: Emergency Management Pocket Guide for Clinicians
- Radiological Terrorism: Just in Time Training for Hospital Clinicians
- Radiation Emergency Assistance Center/Training Site (REAC/TS)
- Radiation Emergency Preparedness and Response
- Radiation Injury Treatment Network (RITN)
- Radiological Terrorism: Toolkit for Emergency Services Clinicians
- Responding to a Radiological or Nuclear Terrorism Incident: A Guide for Decision Makers

Additional Relevant ASPR TRACIE Topic Collections

- Alternate Care Sites (including shelter medical care)
- Burns
- Communication Systems
- Continuity of Operations (COOP)/Business Continuity Planning
- Crisis Standards of Care
- Ethics
- Explosives (e.g., bomb, blast) and Mass Shooting
- Family Reunification and Support
- Fatality Management
- Healthcare Facility Evacuation/Sheltering
- Healthcare-Related Disaster Legal/ Regulatory/ Federal Policy
- Hospital Patient Decontamination
- Hospital Surge Capacity and Immediate Bed Availability
- Incident Management
- Information Sharing
- On-Scene Mass Casualty Triage and Trauma Care
- Patient Movement and Tracking

- Pediatric/Children
- Populations with Access and Functional Needs
- Pre-Hospital
- Pre-Hospital Patient Decontamination
- Recovery Planning
- Responder Safety and Health
- Risk Communications/Emergency Public Information and Warning/Risk Communications
- Utility Failures
- Veterinary Issues
- Virtual Medical Care

Other External Resources

Crisis Standards of Care

The Crisis Standards of Care publication (2012) by the National Academy of Medicine serves as a key CSC foundational document. It includes seven volumes that provide discipline-specific recommendations and assessments tool for CSC planning. States, regions, locals, and healthcare facilities should utilize the guidance provided in the IOM reports, specifically C*risis Standards of Care: A Systems Framework for Catastrophic Disaster Response*, to help develop an operational CSC plan.

- Volume 1, Chapter 2 provides an overview of the CSC framework and planning milestones when developing a plan.
- Volume 1, Chapter 3 provides the legal issues in emergencies that would impact allocation of resources and establishment of CSC.

Hick, J.L., Hanfling, D., and Cantrill, S.V. (2012). Allocating Scarce Resources in Disasters: Emergency Department Principles. Annals of Emergency Medicine. 59(3): 177-187.

The authors summarize key elements contained in the Institute of Medicine work on crisis standards of care. Written for the emergency medicine community, this paper is intended to be a useful adjunct to support discussions related to the planning for large scale disaster incidents.

Hick, J., Hanfling, D., Wynia, M., and Toner E. (2021). Crisis Standards of Care and COVID-19: What Did We Learn? How Do We Ensure Equity? What Should We Do? National Academy of Medicine.

This discussion paper reviews some of the lessons learned related to crisis standards of care principles and practices during the COVID-19 pandemic and identifies issues and action steps for the future.

Crisis Standards of Care Topic Collection

Other Resources

Agency for Healthcare Research and Quality. (2006) Chapter 6. Radiological and Nuclear Terrorism.

This chapter discusses the scope and implications of a radiological or nuclear disaster, including incident management, fallout, and different types of radiation devices or sources.

Agency for Toxic Substances and Disease Registry. (2020). Epi CASE (Contact Assessment Symptom Exposure) Toolkit.
This tool, modeled after the Rapid Response Registry Toolkit, assists public and medical health professionals assess exposure to nuclear or radiological agents after an emergency incident. The data collected can be used to inform epidemiologic need.

Aloise, Gene. (2010). Combating Nuclear Terrorism: Actions Needed to Better Prepare to Recover from Possible Attacks using Radiological or Nuclear Materials. Washington, DC: U.S. Government Accountability Office.

This report details the role of the federal government in helping cities and states clean up after terror attacks using a radiological dispersal device or improvised nuclear device. Recovery activities after the 2006 United Kingdom (UK) polonium incident and the UK Nuclear Recovery Plan Template are also discussed.

American Academy of Pediatrics. (2020). Chemical-Biological Terrorism and Its Impact on Children.

This article discusses the potential disproportionate effects of radiological, chemical, or biological terrorism on children.

American Academy of Pediatrics. (2020). Radiation Disasters and Children.

This article discusses the special medical requirements of children exposed to radiation.

American College of Radiology Disaster Preparedness for Radiology Professionals. (2006). Disaster Preparedness for Radiology Professionals.

This educational resource can be used as a quick reference for preparing for a radiation emergency, managing contaminated patients, and assessing radiation exposure health effects. This resource also includes special considerations for pediatric patients exposed to radiation disasters.

Anzai, K., Ban, N., Ozawa, T., and Tokonami, S. (2012). Fukushima Daiichi Nuclear Power Plant Accident: Facts, Environmental Contamination, Possible Biological Effects, and Countermeasures. Journal of Biochemistry and Nutrition. 50(1): 2-8.

The authors describe the environmental impact of the accident and the primary immediate and delayed biological effects of the radiation. They also highlight potential medical countermeasures to radiation exposure (e.g., iodine tablets, Prussian blue, and radiation modifiers).

Armed Forces Radiobiology Research Institute. (2018). Products and Publications. Uniformed Services University.

This website includes guidelines, handbooks, planning tools, and medical treatment protocols for radiological and nuclear detonation response.

ASPR TRACIE. (2022). CBRN Resources.

These ASPR TRACIE-developed resources can help our stakeholders prepare for, respond to, and help communities recover from chemical/ biological/ radiological/ nuclear incidents.

ASPR TRACIE. (2022). Tips for Retaining and Caring for Staff after a Disaster.

This tip sheet provides general promising practices—categorized by immediate and short-term needs—for facility executives to consider when trying to retain and care for staff after a disaster or during a public health emergency such as the COVID-19 pandemic.

ASPR TRACIE. (2018). EMTALA and Disasters.

This fact sheet addresses several frequently asked questions regarding the Emergency Medical Treatment and Labor Act (EMTALA) and disasters and provides links to resources for more information, but is not intended to be used as regulatory guidance or in place of communications with or guidance from the Centers for Medicare & Medicaid Services (CMS) which oversee EMTALA compliance.

ASPR TRACIE. (2018). Healthcare Challenges After Radiological Incidents.

In this ASPR TRACIE webinar, experts shared tips on assessing, triaging, treating, and following-up with patients affected by radiological and nuclear emergencies. Strategies for handling the initial surge of patients and planning for community reception centers were also discussed.

ASPR TRACIE. (2021). Healthcare Coalition Radiation Emergency Surge Annex Template.

The 2019-2023 HPP Funding Opportunity Announcement (FOA) requires healthcare coalitions (HCCs) to develop a complementary coalition-level radiation emergency surge annex to their base medical surge/trauma mass casualty response plan. This annex aims to improve capacity and capabilities to manage exposed or potentially exposed patients during a radiation emergency.

ASPR TRACIE. (2021). Healthcare System Cybersecurity: Readiness & Response Considerations (Document).

This resource can help healthcare facilities, and the systems they may be a part of, understand the roles and responsibilities of stakeholders before, during, and after a cyber incident.

ASPR TRACIE. (2021). Radiological and Nuclear Topic Collection. Department of Health and Human Services.

This topic collection provides information on radiological release or nuclear detonation incidents which could result in a significant surge of patients.

ASPR TRACIE. (2017). Emergency Prescription Assistance Program (EPAP) Louisiana Floods Data Fact Sheet.

This fact sheet provides a summary of the EPAP data collected and analyzed following the Louisiana flooding from August 19, 2016 to September 20, 2016.

ASPR TRACIE. (2016). Emergency Prescription Assistance Program (EPAP): Overview Fact Sheet.

The Emergency Prescription Assistance Program (EPAP) is funded by the Stafford Act and designed to help disaster survivors access prescription medicines. EPAP can also be activated by the Public Health Service Act under the authority of the National Disaster Medical System (NDMS). The program utilizes normal business operations (e.g., electronic prescription claims processing, utilization of the normal pharmaceutical supply chain for distribution and dispensing) to pay for prescription medications for eligible persons.

ASPR TRACIE. (2016). Emergency Prescription Assistance Program (EPAP): Hurricane Ike Data Fact Sheet.

This fact sheet provides a summary of the EPAP data collected and analyzed following Hurricane Ike from September 12, 2008 to December 15, 2008.

ASPR TRACIE. (2016). Emergency Prescription Assistance Program (EPAP): Hurricane Gustav Data Fact Sheet.

This fact sheet provides a summary of the EPAP data collected and analyzed following Hurricane Gustav from September 2, 2008 to October 31, 2008.

ASPR TRACIE. (2016). Emergency Prescription Assistance Program (EPAP): Superstorm Sandy Data Fact Sheet.

This fact sheet provides a summary of the EPAP data collected and analyzed following Superstorm Sandy for New Jersey and New York through October 30, 2013.

Bagshaw, S. (2014). Population Displacement in the Aftermath of Nuclear Weapon Detonation Events.

This paper, written for and presented at the Vienna Convention of the United Nations describes the humanitarian crisis that would occur following a nuclear weapon detonation.

Baker, G.H. and Volandt, S. (2018). Cascading Consequences: Electrical Grid Critical Infrastructure Vulnerability. Domestic Preparedness.

This article provides an overview of the national power grid, and related threats (e.g., coordinated physical attacks, cyber-attacks against industrial control systems, electromagnetic pulse denotation, and severe solar storms). The authors examine risks, threats, impacts, current state of preparedness, and conclude with recommendations to enhance critical infrastructure resilience.

Balicer, R., Catlett, C., Barnett, D., et al. (2011). Characterizing Hospital Workers' Willingness to Respond to a Radiological Event. PLOS One.

The authors conducted an anonymous survey of more than 18,000 employees of the Johns Hopkins Hospital in 2009 to determine willingness to respond to a radiological event. They found that close to 40% were not willing to respond if asked but not required to do so, and those who perceived their peers as likely to report to work were 17 times more likely to respond if asked. Less than 28% with a perception of low efficacy were willing to respond. The authors emphasize the use of related training to bolster response capabilities.

Becker, S. (2013). From Radiological Incidents to Nuclear Calamities: Social, Behavioral, and Risk Communication Issues in Radiation Emergencies.

This is a 69-minute audio/video recording of a presentation posted by the Institute of Disaster Mental Health. The goal of the training was to increase the knowledge base among emergency and disaster response personnel, as well as the general public, about the probability, effects, and consequences of radiological disasters and the importance of clear risk communication before, during, and after an event or incident.

Becker, Steven M. (2013). The Fukushima Dai-Ichi Accident: Additional Lessons from a Radiological Emergency Assistance Mission. (Abstract only.) Health Physics 105, no. 5 (2013): 455–461.

The author describes response and recovery lessons learned by team members (including an emergency physician, health physicist, and a disaster management specialist) who spent 10 days conducting fieldwork in areas affected by the incident.

Bomanji, J.B., Novruzov, F., and Vinjamuri, S. (2014). Radiation Accidents and Their Management: Emphasis on the Role of Nuclear Medicine Professionals. Nuclear Medicine Communications. 35(10):995-1002.

This article summarizes protocols for decontaminating, assessing, and treating casualties of radiation accidents, and advocates for nuclear medicine specialists to be part of the multidisciplinary care team for these patients. Several relevant tables are also provided in the article.

Bromet, E. (2014). Emotional Consequences of Nuclear Power Plant Disasters. Health Physics. 106(2): 206-210.

This article describes the emotional consequences and resilience of two groups of nuclear power plant disaster survivors: mothers of young children and nuclear plant workers. The authors stress the need for considering physical and mental health "in an integrated fashion," the need for more long-term research, and the need for healthcare providers to be able to recognize and manage psychological symptoms.

Caro, J.J., DeRenzo, E.G., Coleman, C.N. et al. (2011). Resource Allocation After a Nuclear Detonation Incident: Unaltered Standards of Ethical Decision Making. Disaster Medicine and Public Health Preparedness. Volume 5. Supplement 1.

The authors provide practical ethical guidance for healthcare providers faced with making decisions after a nuclear detonation, prior to the establishment of a coordinated response.

Casagrande, R., Wills, N., Kramer, E., et al. (2011). Using the Model of Resource and Time-Based Triage (MORTT) to Guide Scarce Resource Allocation in the Aftermath of a Nuclear Detonation. Disaster Medicine and Public Health Preparedness. Volume 5. Supplement 1.

The authors used the model of resource- and time-based triage (MORTT) and found that in settings where resources were scarce, prioritizing victims with moderate life-threatening injuries over victims with severe life-threatening injuries saves more lives and reduces demand for intensive care.

Centers for Disease Control and Prevention. (2005). Cutaneous Radiation Injury: Fact Sheet for Physicians.

This resource for physicians describes symptoms, stages, severity, and management of patients affected by cutaneous radiation injury, or injury to the skin caused by a large dose of radiation.

Centers for Disease Control and Prevention (2011). Virtual Community Reception Center.

This interactive webpage is designed as a planning/training experience where users learn how to describe the process flow, identify key stations, and recognize essential services for each station in a community reception center.

Centers for Disease Control and Prevention. (2014). Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners. Second Edition.

This guide provides information for state and local planners to develop post radiological emergency response plans. This guide describes processes for managing the radiation monitoring required to evaluate exposure in the affected population, including the use of community reception centers.

Centers for Disease Control and Prevention. (2014). Radiological Terrorism A Tool Kit for Emergency Services Clinicians.

This toolkit contains resources (such as videos and pocket guides) on decontamination, population monitoring, and psychological first aid in radiation emergencies.

Centers for Disease Control and Prevention. (2015). Radiation and Your Health.

This webpage includes information for individuals on the effects of ionizing and non-iodizing radiation. Separate tabs provide information on “Radiation in Your Life,” “Health Effects of Radiation,” and “Radiation Basics.”

Centers for Disease Control and Prevention (2017). Community Reception Center (CRC) Drill Toolkit.

The CRC Drill toolkit provides guidance and templates that any jurisdiction can adapt to exercise the full range of CRC operations. The drill was developed to be compatible with the U.S. Department of Homeland Security's Homeland Security Exercise and Evaluation Program (HSEEP). It also incorporates insights, issues, and lessons learned from real-world events.

Centers for Disease Control and Prevention. (2018). Acute Radiation Syndrome.

This website provides information on acute radiation syndrome (ARS), also known as radiation sickness, for the public.

Centers for Disease Control and Prevention. (2018). Cutaneous Radiation Injury (CRI).

This website contains information on injury to the skin due to a large dose of radiation, known as cutaneous radiation injury.

Centers for Disease Control and Prevention. (2018). Information for Clinicians.

This webpage provides links to information on patient management, guidelines and recommendations, training, and the "Radiological Terrorism: Toolkit for Emergency Services Clinicians."

Centers for Disease Control and Prevention. (2018). Radiation Emergency Training, Education and Tools.

This webpage offers links to educational videos, resource tools, online training modules, and webinars designed to prepare public health and healthcare professionals to respond to radiation emergencies and disasters.

Centers for Disease Control and Prevention. (2019). Radiation Emergencies: Information for Professionals.

This webpage contains links to resources for clinicians treating victims of radiation emergencies, public health preparedness capabilities, and information for radiological terrorism planning.

Centers for Disease Control and Prevention. (n.d.). SimPLER. (Accessed 8/10/2022.)

Emergency managers can use the Simulation Program for Leveraging and Evaluating Resources, or SimPLER, to simulate planning bottlenecks, staffing, and throughput capacity to plan for many kinds of emergencies. Based on data from emergency exercises around the country, SimPLER includes modules on community reception centers and points of dispensing.

Centers for Disease Control and Prevention. (2020). Radiation Response Briefing Manual. United States Department of Health and Human Services.

This concise guide provides decisionmakers with information about types of radiation and different radiological and nuclear incidents and incorporates useful tables and figures. It discusses which decisions need to be made when, the roles of different agencies, relevant assets, measuring radiation doses, radioprotective medications, and key public health actions that must be taken (e.g., screening and registries).

Centers for Disease Control and Prevention, Emergency Preparedness and Response. (2015). Virtual Community Reception Center (vCRC).

This web-based training tool teaches emergency healthcare planners how to conduct population monitoring after a mass casualty radiation emergency in community reception centers.

Centers for Disease Control and Prevention, National Center for Environmental Health. (2015). A Guide to Operating Public Shelters in a Radiation Emergency.

This document can assist emergency managers with planning and response efforts related to shelter operations in a radiation emergency. The guide includes information on screening for radioactive contamination, decontamination, radiation monitoring, registration, health surveillance, and communications consistent with Centers for Disease Control and Prevention Community Reception Center guidance. Chapter Three of this guidance document shares strategies for screening and decontamination (of people, service animals, pets, possessions, and vehicles) in shelters. Quick guides on decontamination are provided as appendices.

Chaffee, M. (2009). Willingness of Health Care Personnel to Work in a Disaster: An Integrative Review of the Literature. Disaster Medicine Public Health Preparedness. 3(1):42–56

The author conducted a literature review (25 quantitative and 2 qualitative studies) on willingness to work and found pet care needs and the lack of personal protective equipment were top barriers.

Coleman, N. (2015). Public Health and Medical Preparedness for a Nuclear Detonation: The Nuclear Incident Medical Enterprise. Health Physics.

The authors summarize Nuclear Incident Medical Enterprise (NIME), the approach developed by the U.S. Department of Health and Human Services by both government and non-government experts. NIME can be used by emergency healthcare planners to support planning for, responding to, and recovering from the effects of a nuclear incident.

Coleman, C.N., Knebel, A. R., Hick, J.L. et al. (2011). Scarce Resources for Nuclear Detonation: Project Overview and Challenges. Disaster Medicine and Public Health Preparedness. Volume 5. Supplement 1.

This article summarizes the medical challenges associated with scarce resources and nuclear detonations, and serves as an introduction to the rest of the articles in this special issue on nuclear detonation.

Coleman, C.N., Weinstock, D.M., Casagrande, R. et al. (2011). Triage and Treatment Tools for Use in a Scarce Resources-Crisis Standards of Care Setting After a Nuclear Detonation. Disaster Medicine and Public Health Preparedness. Volume 5. Supplement 1.

Based on the information shared in other articles in this issue, the authors discuss possible triage options during the first four days after an event.

Department of Homeland Security (DHS). (2016). Nuclear Radiological Incident Annex to the Response and Recovery Federal Operational Interagency Operational Plans October 2016.

This planning tool consists of a base document and three corresponding incident-specific planning documents. The base document covers general guidance applicable to all radiological and nuclear incidents, and the other documents provide guidance for suspected or deliberate attacks, inadvertent incidents, and international incidents. This annex can be used by federal, state, local, and voluntary organizations to enhance planning efforts and ensure coordination with federal planning efforts.

Department of Homeland Security (DHS). (2016). Health and Safety Planning Guide for Planners, Safety Officers, and Supervisors for Protecting Responders Following a Nuclear Detonation.

This planning guide can help agencies improve planning for and protection of responders following a nuclear detonation event. The guide covers topic areas such as incident command, responder safety, decontamination, site control, personal protective equipment, radiation detection and air monitoring equipment, training, communications, and record keeping.

Department of Homeland Security. (2017). Radiological Dispersal Device (RDD) Response Guidance Planning for the First 100 Minutes November 2017 .

This planning document provides guidance to first responders and local response agencies in understanding the critical missions and tasks that should be undertaken within the first 100 minutes of a radiological dispersal device denotation response. Public messaging, response coordination, personal protective equipment, and equipment resource recommendations are reviewed within the document. The authors also include customizable planning tools and worksheets.

DiCarlo, A.L., Maher, C., Hick, J.L. et al. (2011). Radiation Injury After a Nuclear Detonation: Medical Consequences and the Need for Scarce Resources Allocation. Disaster Medicine and Public Health Preparedness. Volume 5. Supplement 1.

This literature review focuses on radiation injuries from human exposures and animal models and is accompanied by various triage and management approaches (covered in the rest of this special issue).

Dodgen, D., Norwood, A., Becker, S., et al. (2017). Social, Psychological and Behavioral Responses to a Nuclear Detonation in a US City: Implications for Healthcare Planning and Delivery. Disaster Medicine and Public Health Preparedness. 5(Suppl. 1).

The authors reviewed literature on human responses to radiation incidents and disasters in general, with a focus on behavioral health care provider (BHCP) contributions in the hours and days after a nuclear detonation. They listed the following six broad categories of interventions: promoting appropriate protective actions, discouraging dangerous behaviors, managing patient/survivor flow to facilitate the best use of scarce resources, supporting first responders, assisting with triage, and delivering palliative care when appropriate. The authors also shared recommendations regarding response and recovery phase BHCP interventions.

Eckerman, K. and Ryman, J. (1993). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12. Oak Ridge National Laboratory.

Based on federal guidance, the authors provide a "framework to ensure that the regulation of exposure to ionizing radiation is carried out in a consistent and adequately protective manner." The report includes tables of dose coefficients, application considerations, and several appendices.

EMP Commission. (2017). Volume I, Assessing the Threat from EMP Attack – Executive Report.

This report provides in-depth details, findings, and recommendations from the EMP Commission on intentional and solar superstorm electromagnetic pulse incidents. The Commission highlights challenges and current planning status, and provides overarching recommendations to improve and mitigate against current threats critical infrastructure systems.

EMP Commission. (2018). Volume II, Recommended E3 HEMP Heave Electric Field Waveform for the Critical Infrastructures.

This report reviews the EMP Commission recommendations for HEMP preparedness to ensure critical infrastructure protection. The authors utilized data from Soviet-era nuclear tests to provide recommendations to protect critical infrastructure against threats and vulnerabilities associated with High Altitude Electromagnetic fields.

Federal Emergency Management Agency. (2008). Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents.

This guidance can be used by community leaders to help plan for, respond to, and recover from RDD and IND incidents. It describes the various phases of an incident; includes a figure that depicts exposure routes, protective measures, and timelines for effects; lists protective actions; and highlights late phase/recovery activities for planning purposes.

Federal Emergency Management Agency. (2010). Millstone Power Station. After-Action Report/Improvement Plan.

This report covers the June 30, 2010 Host Community Reception Center (CRC) Drill conducted in Windham, CT. The Improvement Plan highlights recommendations and adjudications to the state CRC plan specific to the performance of offsite response organizations. Appendices are included; Appendix C specifically covers the CRC

Federal Emergency Management Agency. (2013). Improvised Nuclear Device Response and Recovery Communicating in the Immediate Aftermath.

This report discusses communications after a nuclear or radiological emergency.

Federal Emergency Management Agency. (2020). Radiological Operations Support Specialist (ROSS). U.S. Department of Homeland Security.

This website describes the role of Radiological Operations Support Specialists (ROSS), a team of subject matter experts who provide critical information to decisionmakers in case of a radiological emergency. These experts are available to state, local, tribal, and territorial emergency managers to plan and respond to radiological emergencies.

Federal Emergency Management Agency. (2022). Planning Guidance for Response to a Nuclear Detonation. Third Edition. Homeland Security Council Interagency Policy Coordination Subcommittee for Preparedness and Response to Radiological and Nuclear Threats.

This core resource document provides emergency planners (including emergency medical service planners, medical receiver planners, and mass care providers) recommendations specific to nuclear detonation incidents in an urban setting.

Federal Emergency Management Agency. (2022). Interagency Modeling and Atmospheric Assessment Center (IMAAC).

This webpage describes the role of the center, which is to coordinate and disseminate federal atmospheric dispersion modeling and hazard prediction products and provide the federal position during actual or potential incidents involving hazardous material releases.

Florida Department of Health. (2011). After-Action Report and Improvement Plan Matrix.

This report covers the July 12, 2011, Community Reception Center (CRC) Drill conducted at Cypress Creek High School in Orlando, Florida. The Improvement Plan highlights recommendations and adjudications to the state CRC plan. Appendices are included.

Florida Department of Health. (n.d.). Community Reception Center (CRC) Form. (Accessed 8/23/2022.)

First responders can use this intake form as a model when creating their own CRC forms. It includes incident-specific questions and two pages of instructions.

Frankel, M., Scouras, J., and De Simone, A. (2015). Assessing the Risk of Catastrophic Cyber Attack. Lessons from the Electromagnetic Pulse Commission. Johns Hopkins Applied Physics Laboratory.

The authors describe the Electromagnetic Pulse (EMP) Commission mandate and the group's approach and highlight the similarities and differences between EMPs and cyberattacks.

Health Physics Society. (n.d.). Specialists in Radiation Protection. (Accessed 10/4/2022).

This website contains information on radiation safety and protection in the context of disease diagnosis and therapy, scientific research, and electrical power.

Health Physics Society. (2016). What Types of Radiation Are There?

This webpage describes the characteristics of alpha radiation, beta radiation, gamma radiation, and x radiation.

Healthcare & Public Health Sector Coordinating Councils. (n.d.) Planning for Power Outages: A Guide for Hospitals and Healthcare Facilities. (Accessed 10/47/2022.) U.S. Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response.

This document highlights issues for healthcare facilities to consider regarding power outages. It also provides a checklist of key planning considerations, and recommendations for fostering a relationship with a facility's utility company.

Healthcare Ready. (2019). Rx Open.

This website helps emergency management teams and the general public locate operating pharmacies in areas affected by natural disasters or public health emergencies. The tool provides maps to identify the location of open and closed pharmacies using Google Maps. The website is free to the public when activated at the request of state or federal officials.

Hick J., Weinstock D., Coleman C., et al. (2011). Health Care System Planning and Response for a Nuclear Detonation. Disaster Medicine and Public Health Preparedness. Volume 5. Supplement 1.

The U.S. Department of Health and Human Services developed a State and Local Planners Playbook, which includes guidance on the medical response to a nuclear detonation. The authors of this article provide additional (discipline-specific) information and analysis on the recommended actions identified in the playbook.

Hick, J. and Coleman, N. (2018). Population-Based Triage, Treatment, and Evacuation Functions Following a Nuclear Detonation.

This discussion paper describes the screening function (Exposure And Symptom Triage – EAST) which will primarily be conducted at Assembly Centers after a nuclear detonation. Geared towards jurisdictional emergency planners and responders as a planning reference, it contains response tools and strategies that will assist them in planning for Assembly Centers and mass screening functions.

The Institute of Medicine. (2012). Crisis Standards of Care: A Systems Framework for Catastrophic Disaster Response: Volume 1: Introduction and CSC Framework.

This book discusses healthcare operations during crisis standards of care after many kinds of disaster, including radiation emergencies.

International Atomic Energy Agency. (2000). Management of Radioactive Waste from the Use of Radionuclides in Medicine.

This document describes how to handle radionuclides after they are used therapeutically in medicine.

International Atomic Energy Agency. (2014). Final Report: The Follow-Up IAEA International Mission on Remediation of Large Contaminated Areas Off-Site the Fukushima Daiichi Nuclear Power Plant.

Chapter 5 of this report covers the "Remediation Strategy Implementation," including hard surface and building decontamination techniques and guidelines, food and agricultural safety, and forest and aquatic area remediation. A chapter on waste management with guidelines on storing contaminated materials follows.

Japan-guide.com. (2022). Fukushima Prefecture.

This travel-related website includes a map of the affected area with current radiation readings.

Jones, L., Moor, D., Peacock, T., et al. (2020). Assessment of the Potential Impact of Embedded Radioactive Fragments Following the Use of a Crude Radiological Dispersal Device ('Dirty Bomb'). (Abstract only.) Journal of Radiological Protection. 40(4).

The authors discuss the implications and management of radiological dispersal device/dirty bomb patients with "hot" fragments embedded in their bodies.

Kinley III, D. (2006). Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine. International Atomic Energy Agency.

This report includes follow-up healthcare-specific recommendations for select populations in affected areas and suggestions for future research. Environmental monitoring and remediation suggestions are also provided, followed by recommendations for economic and social policy.

Kornei, K. (2017). It's Safe to Return to Some Parts of Fukushima, Study Suggests. Science.

The author describes efforts to study radiation levels in villages surrounding Fukushima and explains that the amount of rain and snow contributed to the eventual decay of the radioactive cesium.

Linet, M., Kazzi, Z., Paulson, J., and The Council on Environmental Health. (2018). Pediatric Considerations Before, During, and After Radiological or Nuclear Emergencies. (Abstract only.) Pediatrics. 142(6).

The authors describe the unique pediatric risks from radiation events and the need for ongoing monitoring after an event. They complement this discussion with results from prior radiation events such as Chernobyl and Fukushima.

Lochard, J. and Prêtre, S. (1995). Return to Normality after a Radiological Emergency. Health Physics. 68(1): 21–26.

While slightly dated, the information in this article is focused on helping communities understand how to determine post-incident acceptability (or "return to normal"). The various components covered by the authors include time post-incident, the zoning process (including the negative effects of establishing zones), and the "reference to the norm."

Los Angeles County. (2009). Playbo xzzxxxxok 9: Monitoring People for Contamination at Public- Reception Centers. Los Angeles County Multi-Agency Radiological Response Plan.

This document provides steps for responders to take upon receipt of residents at Community Reception Centers. It includes forms for responders and handouts for visitors.

Los Angeles County (2009). Community Reception Center Flow Diagram.

This is a set of floorplans for various stages of CRCs, including intake, emergency medical care or transfer, and discharge.

Minnesota Department of Health. (2011). Patient Care Strategies for Scarce Resource Situations. Center for Infectious Disease Research and Policy.

This tool provides insight into preparation and response to shortages of oxygen, staff, nutrition, medications, or other materials needed for a functioning healthcare system.

Morimura, N., Asari, Y., Yamaguchi, Y., et al. (2013). Emergency/Disaster Medical Support in the Restoration Project for the Fukushima Nuclear Power Plant Accident. Emergency Medical Journal. 30: 997-1002.

The authors describe the medical response to the incident, including patient decontamination. Photos of the decontamination tent and tables illustrating diagnosis and patient outcome are included.

Moskowitz, S. (n.d.). Disaster Mental Health: Assisting People Exposed to Radiation. (Accessed 8/23/2022.)

This presentation describes the prominent psychosocial issues related to radiological exposure, examines the evidence-based psychosocial interventions, including effective risk communication practices, and identifies key elements of self-care for first responders and public health professionals.

National Council on Radiation Protection and Measurements. (2015). NCRP Commentary No. 19, Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism.

This commentary discusses how the Department of Homeland Security, and state and local officials can prepare for terrorist incidents involving radiation exposure.

National Guard. (2017). Weapons of Mass Destruction (WMD) Civil Support Team (CST).

This fact sheet describes the role of the National Guard in supporting CBRNE incidents.

National Nuclear Security Administration. (n.d.). Nuclear Emergency Support Team (NEST). (Accessed 10/3/2022.)

This webpage describes the role of the NEST and describes several elements/teams used to plan for and respond to nuclear emergencies.

Nevada National Security Site. (n.d.) Federal Radiological Monitoring and Assessment Center (FRMAC). (Accessed 10/4/2022).

This webpage describes the roles of the center, which include: helping with verified radiation measurements; interpreting of radiation distribution based on Environmental Protection Agency, U.S. Food and Drug Administration, and/or local Protective Action Guidelines; and interpreting overall radiological conditions.

Nisbet, A. and Chen, S. (2013). Decision Making for Late Phase Recovery from Major Nuclear or Radiological Incidents.

This presentation details the late-phase recovery framework and includes helpful graphics and emphasizes the importance of stakeholders in the recovery process. The authors discuss seven “optimization steps” and the eight recommendations provided in the report.

Nuclear Medicine Radiochemistry Society. (2003). Medical Isotopes: General Concepts.

This webpage describes isotopes and covers areas such as stability, applications, definitions, diagnostic/therapeutic properties, and isotopes in medicine.

Oak Ridge Institute for Science and Education (ORISE). (n.d.). Radiation Countermeasures. (Accessed 10/4/2022).

This website contains information on radiation countermeasures such as Radiogardase Prussian Blue, calcium-DTPA, and zinc-DTPA.

Oak Ridge Institute for Science and Education (ORISE). (n.d.). Radiation Emergency Assistance Center/ Training Site (REAC/TS). (Accessed 8/23/2022.)

This webpage links to the Radiation Emergency Assistance Center/Training Site (REAC/TS), which offers several resources to prepare medical professionals to respond to radiological emergencies. There are links to books, live training courses, online trainings, and assessment and treatment guidance documents. REAC/TS staff are available for deployment to provide medical consultation during emergencies, upon request.

Oughton, D., Albani, V., Barquinero, F., et al. (2020). Recommendations and Procedures for Preparedness and Health Surveillance of Populations Affected by a Radiation Accident. ISGlobal, Barcelona Institute for Global Health.

These recommendations incorporate social, ethical, psychological issues and are geared towards surveilling health and communicating with affected populations after nuclear accidents.

Public Health England. (2015). UK Recovery Handbooks for Radiation Incidents 2015.

These handbooks cover the radiation incident recovery process for food production, inhabited areas, and drinking water.

Radiation Emergency Medical Management (REMM). (2017). A Decision Makers Guide: Medical Planning for a Nuclear Detonation, Second Edition.

This guide describes scientific and medical information of use in a radiological emergency.

Radiation Emergency Medical Management (REMM). (2017). A Decision Makers Guide: Medical Planning for a Nuclear Detonation, Second Edition.

This guide describes scientific and medical information of use in a radiological emergency.

Radiation Emergency Medical Management (REMM). (2018). Exposure and Symptom Triage (EAST) Tool to Assess Radiation Exposure After a Nuclear Detonation.

This tool assists with triage during a radiological incident.

Radiation Emergency Medical Management (REMM). (n.d.). Radiation Triage, Treat, and Transport System (RTR) after a Nuclear Detonation: Venues for the Medical Response. (Accessed 10/4/2022).

This webpage describes different areas of radiation exposure after a nuclear detonation.

Radiation Emergency Medical Management (REMM). (n.d.). Recovery / Resilience after an Incident: Useful Guidance about Recovery and Resilience. (Accessed 8/23/2022).

This section of this REMM webpage includes links to guidance specific to response to and recovery from incidents.

Radiation Emergency Medical Management (REMM). (n.d.). Recovery / Resilience after an Incident: Useful Guidance about Recovery and Resilience. (Accessed 8/23/2022).

This section of this REMM webpage includes links to guidance specific to response to and recovery from incidents.

Radiation Injury Treatment Network. (2022). Radiation Injury Treatment Network.

This website contains many resources for preparing to and responding to radiological and nuclear incidents, from treatment to triage, training, exercises, and other resources.

Radiation Injury Treatment Network. (2011). RITN Radiation Patient Treatment AFRRI Pocket Guide.

This guide provides a flowchart for decision making when treating patients affected by radiation.

Radiation Response Volunteer Corps and Population Monitoring. (n.d.). Radiation Response Volunteer Corps and Population Monitoring. (Accessed 8/23/2022.)

This website includes a "Templates and Forms" tab that takes the user to a Dropbox page. Links to templates follow:

Kansas Community Center Flow Diagram

Kansas Radiation Incident Community Reception Center Standard Operating Guidelines

Kansas Department of Health and Environment CRC Template

Union County (OH) Example CRC Supply and Equipment List

Rojas-Palma, C., Steinhäusler, F., Kuča, P., et al. (2020). Guidelines for First Responders Based on Results from Deploying a Mockup Radiological Dispersal Device. (Abstract only.) Journal of Radiological Protection. 28(4).

The authors carried out and analyzed several passive agent dispersions with improvised explosive devices and vehicle-borne improvised explosive devices. They estimated that considerable radiation levels could be found up to 50 meters from ground zero, making full protective gear (including full-face protective gear) a must for rescue personnel. The authors also emphasized the need for on-scene assessment of radiation and a solid understanding of exposure thresholds.

Rump, A., Eder, S., Hermann, C., et al. (2021). Estimation of Radiation-Induced Health Hazards from a "Dirty Bomb" Attack with Radiocesium Under Different Assault and Rescue Conditions. Military Medical Research. 8.

The authors provide an in-depth discussion of risks and considerations of a Cs-137 "dirty bomb" response including modeling that demonstrates low relative risk of significant radiation exposures.

Schoch-Spana, M. (2013). Rad Resilient City: A Preparedness Checklist to Save Lives Following a Nuclear Detonation. Center for Biosecurity of UPMC.

This checklist provides information to diminish loss of lives following a nuclear detonation. This tool should be used as a preparedness tool and during planning.

Sherman, S. (2011). Legal Considerations in a Nuclear Detonation. Disaster Medicine and Public Health Preparedness. Volume 5. Supplement 1.

Although the focus of the article is nuclear events, it provides a general overview of legal authorities relevant to emergencies.

Shimura, T., Yamaguchi, I., Terada, H., et al. (2015). Public Health Activities for Mitigation of Radiation Exposures and Risk Communication Challenges after the Fukushima Nuclear Accident. (Abstract only.) Journal of Radiation Research. 56(3): 422-429.

The authors discuss the range of response actions and public health mitigation efforts taken following the Fukushima reactor incident and highlight the difficult decisions that need to be made in real-time about acceptable levels of radiation/contamination.

Singh, V., Romaine, P., and Seed, T. (2015). Medical Countermeasures for Radiation Exposure and Related Injuries: Characterization of Medicines, FDA-Approval Status and Inclusion into the Strategic National Stockpile. Health Physics. 108(6): 607-630. (Abstract only.)

The authors list and review the status of radiation countermeasures that were available for use (as of 2015).

Tanisho, Y., Smith, A., Sodeoka, T., and Murakami, H. (2015). Post-Disaster Mental Health in Japan: Lessons and Challenges. Health and Global Policy Institute.

This report describes lessons learned from the Fukushima nuclear disaster in 2012. It includes recommendations for ensuring that psychosocial and mental health interventions consider the unique circumstances and cultural issues of a given disaster.

Transportation Emergency Preparedness Program. (2007). TEPP Planning Products-Model Procedure for Medical Examiner/Coroner on the Handlinpog of a Body/Human Remains that are Potentially Radiologically Contaminated.

This document can help medical examiners/coroners handle a body or human remains that are potentially contaminated with radioactive material from a transportation incident.

Tsubokura, M., Gilmour, S., Takahashi, K., et al. (2012). Internal Radiation Exposure After the Fukushima Nuclear Power Plant Disaster. Journal of the American Medical Association. 308(7): 669-670.

This study examined cesium levels in a sample of residents from Minamisoma, a town located 23 kilometers north of the Fukushima Daiichi nuclear plant, six months after the accident. A total of 3286 individuals had detectable levels of cesium and levels were statistically higher in adults than children; no cases of acute health problems were reported to the team at the time the article was published.

U.S. Department of Agriculture. (n.d.). Radiation Safety: Dose Limits.

This website discusses proper use of dosimeters in radiation safety.

U.S. Department of Energy, The Electric Power Research Institute. (2016). Joint Electromagnetic Pulse Resilience Strategy .

This document presents guidance to support and improve response and recovery efforts after an electromagnetic pulse (EMP) denotation. It provides 5 strategic goals to assist energy sector officials in planning and response to minimize EMP impacts and ultimately enhance resilience.

U.S. Department of Health and Human Services. (2022). HHS emPOWER Program Platform.

The HHS emPOWER Program is a mission-critical partnership between the Administration for Strategic Preparedness and Response (ASPR) and the Centers for Medicare and Medicaid Services (CMS). The program provides federal data, mapping, and artificial intelligence tools, as well as training and resources, to help communities nationwide protect the health of at-risk Medicare beneficiaries, including 4.4 million individuals who live independently and rely on electricity-dependent durable medical and assistive equipment and devices, and or essential health care services.

U.S. Department of Health and Human Services, Office of the Assistant Secretary for Preparedness and Response. (2022). Emergency Prescription Assistance Program (EPAP).

The purpose of the EPAP is to perform the activities related to processing claims for prescription medications, vaccines, specific medical supplies and certain durable medical equipment for designated eligible individuals in a federally identified disaster area. The activation of EPAP is requested through the states' department of health in their emergency management agency. The program can then provide a 30-day supply of covered drugs and medical supplies that can be renewed every 30 days for as long as EPAP is active.

U.S. Department of Health and Human Services. (2011). State and Local Planners Playbook for Medical Response to a Nuclear Detonation.

This playbook provides guidance to state, regional, local, tribal, and territorial sectors; medical professionals; public health planners; and other subject matter experts who are developing plans for a medical response to a nuclear detonation.

U.S. Environmental Protection Agency (EPA). (n.d.). Radiation Protection.

This website provides links to resources that can help protect communities from radiation (e.g., a dose calculator, basic information, protective actions, regulations, and response). A document library and links to related content are also provided.

U.S. Environmental Protection Agency (EPA). (2017). PAG Manual Protective Action Guides and Planning Guidance for Radiological Incidents January 2017.

This manual can help public officials plan for emergency response to radiological incidents. The manual consists of two overarching response areas: protective action guides, and protective actions which are further broken down into early, intermediate, and late phase response actions for radiological incidents. Each phase describes corresponding response actions (e.g., evacuation, sheltering in place, administration of medication, worker protection, and clean up, and disposal of radiological waste).

U.S. Food and Drug Administration. (2018). FDA Approves Leukine for Acute Radiation Syndrome.

This article announces the FDA's approval of a new treatment for radiation sickness.

U.S. Food and Drug Administration. (2021). Radiological and Nuclear Emergency Preparedness Information from FDA.

This webpage discusses updates to FDA's radiological and nuclear preparedness efforts, including the lifted import alert for Japanese products originating from the region near the Fukushima disaster, regulatory updates, and a new treatment for acute radiation syndrome.

U.S. Nuclear Regulatory Commission. (2020). Emergency Planning Zones.

This webpage discusses how to plan for emergencies around a nuclear power plant.

U.S. Nuclear Regulatory Commission. (2020). What are the Different Types of Radiation?

This webpage describes alpha, beta, neutrons, and electromagnetic waves such as gamma rays and how they differ in terms of mass, energy and how deeply they penetrate people and objects.

Ubaura, M. (2013). Reconstruction Urban Planning: Current Status and Future Challenges. The Great East Japan Earthquake 2011 Case Studies.

This article presents a snapshot of the recovery process in Japan after the 2011 earthquake. Chapter 3 explains the long-term recovery process from urban planning, community development, and specific population perspectives.

University of Alabama at Birmingham. (2007). Accepted Half-Lives of Commonly Used Radioisotopes.

This chart lists all radioactive isotopes with greater than 100 year half-life. An element decays to undetectable levels within 10-15 half-lives (6 half-lives is good estimate).

Vandre, R., Klebers, J., Tesche, F., and Blanchard, J. (1993). Electromagnetic Pulse (EMP), Part I: Effects on Field Medical Equipment. Military Medicine. 158(4):233-236.

The authors examined the simulated damage of an EMP incident and found that current surge on power cords and leads were the most likely challenges affecting more than 50% of electronic medical equipment in the field.

Various Authors. (2016). The Radiation Safety Journal: Health Physics. Volume 110, Issue 5. (Paid access unless subscriber.)

This special issue contains articles that illustrate the distribution of radioactive materials following radiation dispersal device detonations based on actual testing as well as modeling, with implications for responding agencies.

Various Authors. (2022). The Radiation Safety Journal: Health Physics. Volume 122, Issue 1. (Paid access unless subscriber.)

This special issue of Health Physics is dedicated to describing methods of assessing and estimating fallout exposures.

Veenema, T., Walden, B., Feinstein, N. and Williams, J. (2008). Factors Affecting Hospital-based Nurses' Willingness to Respond to a Radiation Emergency. Disaster Medicine and Public Health Preparedness. 2(4):224-9.

This article includes results from a survey of hospital-based nurses conducted to evaluate their baseline knowledge; self-assessed clinical competence; perception of personal safety; and willingness to respond in the event of a radiological emergency. Baseline knowledge was found to be inadequate among respondents. Baseline knowledge, clinical competence, and perception of personal safety were all positively associated with willingness to respond, and the authors recommend additional clinical training to prepare nurses to respond to a radiation emergency.

Washington State Department of Health. (n.d.). State Radiological Emergency Preparedness Agencies. (Accessed 8/23/2022.)

This webpage provides links to each U.S state's specific radiological emergency preparedness agency or organization. This streamlined list provides a way to identify each state's radiation public health page along with contract information and resources. (Note that some of the links in the table are broken.)

Wolbarst, A.B., Wiley, A.L. Jr., Nemhauser, J.B. et al. (2010). Medical Response to a Major Radiologic Emergency: A Primer for Medical and Public Health Practitioners. Radiology. 254(3):660-77.

This article reviews the types of radiation incidents and the radiation injuries that would be sustained by casualties of a nuclear or radiologic device detonation, or accidental release, such as from a power plant, as well as how to treat them. It also describes the important role physicians who understand the effects of radiation on the human body and how to treat them, will play during a radiological or nuclear emergency

World Health Organization. Radiation Emergency Medical Preparedness and Assistance Network (REMPAN).

This website from the World Health Organization provides emergency medicine and public health information for people suffering from radiation injury or exposure.

Yasumura, S., Hosoya, M., Yamashita, S., et al. (2012). Study Protocol for the Fukushima Health Management Survey. Journal of Epidemiology. 22(5): 375-383.

The authors conducted a basic survey to estimate radiation levels in the Fukushima Prefecture and used results from four detailed surveys to understand the effects of the incident on thyroid levels for all Fukushima children; overall mental and physical health for all residents from the evacuation zones; and all pregnancies and births among all women in the prefecture who were pregnant on 11 March. The authors acknowledged a low response rate but also noted no malignancies among thyroid ultrasound recipients and the overall importance of mental health care.