NYC Health

Rapid Response Actions for the Emergency Department in an Explosive Mass Casualty Radiological Incident

Contents

Radiological Emergency Resources

The **New York City Department of Health and Mental Hygiene's (NYC Health Department) Poison Center** is available 24/7 and can provide treatment advice and information about potential poisons and medicine safety. Call 212-POISONS (212-764-7667). You may also report a contaminated emergency department (ED) patient to the NYC Poison Center at any time at that number or to the NYC Health Department Office of Radiological Health from 9 a.m. to 5 p.m. by calling 718-786-6002.

The **Radiation Emergency Assistance Center/Training Site (REAC/TS)** provides 24/7 emergency response and subject matter expertise on the medical management of radiation incidents. Call 865-576-3131 (or call 865-576-1005 after hours and ask for REAC/TS) or email **reacts@orau.org**. Providing the following information will help REAC/TS address your questions and concerns:

- Your name, position or title, location, and phone number or email address
- Whether the incident was an exposure or contamination event
  - If the incident was a contamination event, indicate whether the patient was surveyed, the results and the units of radiation detection used.
- Whether an isotope or device was involved
- The patient's current medical status, including vital signs and symptoms, and relevant medical history
- Whether any lab or diagnostic tests have been conducted
- Whether the patient was wearing a dosimeter
- Whether any other departments have a radiation safety officer (RSO) and whether they have been contacted

Radiation Emergency Medical Management (REMM) provides extensive guidance on the diagnosis and treatment of radiation injuries for health care providers. Visit **remm.hhs.gov** for:

- Training on radiation, radiological incidents and radiation injury
- Decontamination procedures
- Patient management, including guidance on contamination, exposure, algorithms and triage
- Information on acute radiation syndrome (ARS)
- Burn triage and treatment
- Management of the deceased

The **Centers for Disease Control and Prevention's (CDC)** Information for Clinicians webpage provides information on patient management, guidelines and recommendations, and training. Visit **cdc.gov** and search for **information for clinicians radiation emergencies**.

Purpose of This Document

The ED has been alerted to a radiological incident. Patients who are radiologically contaminated will be arriving soon. How should the ED respond?

Radiation emergencies involving injuries or toxic uptake of radioisotopes are rare but can occur. The term "dirty bomb" (or "radiological dispersal device" [RDD]) – a device that combines radioactivity with explosives – gives images of people covered in radioactive dust and debris, potentially resulting in inhalation, ingestion or uptake of radioactivity through wounds into the body. Medical emergency providers will be expected to triage, diagnose and treat patients despite having little or no previous experience with radiation injuries.

This document is a rapid response guide on how to jump-start the response to an emergency radiological incident and prepare for and execute treatment of patients who are injured when radioactive contamination is present. It will not explain how to treat radiation injuries or diagnose acute radiation syndrome (ARS) but rather how to:

- Recruit help in answering a variety of radiological questions from knowledgeable staff within the facility
- Rapidly prepare the ED for the arrival of patients who are radiologically contaminated
- Effectively work with multiple patients who are radiologically contaminated
- Assess and prioritize patients who have experienced trauma for treatment, from triaging and managing injuries from various exposure levels to observation and surgery options
- Treat patients who are pregnant during a radiological emergency
- Determine the symptoms of external radiation exposure versus external and internal radiation contamination

Important Reminders

- As is customary for ED staff, treating and stabilizing patients who are injured must take priority over radiological considerations.
- External radiological contamination can come in the form of liquid, powder, dust, debris or shrapnel found on the outside of the body that contains radioactive materials.
- Most amounts of radiological contamination entering the ED with patients who need care are not expected to be acutely dangerous.
- Be familiar with the staff members at the facility who can assist with radiation questions, including the RSO or medical physics staff.

Note: The recommendations in this document apply to the first few hours after an explosive radiological incident has occurred (also known as the "early phase"). This document does not attempt to fully describe detailed exposure dose assessments, prolonged medical management or follow-up of ARS (radiation poisoning, sickness or toxicity) or long-term management of internal contamination. Many other sources address these long-term situations (such as the CDC's, REAC/TS' and REMM's websites, textbooks and other references). Readers are encouraged to review these sources for more detailed management protocols.

Preparing the Staff and Facility

If you are preparing ED staff and the facility in advance for working with patients who are radiologically contaminated, read "Working Safely With Radiological Contamination" on Page 31. You can also review the modes of radiological exposure by reading "For Your Safety: Radiation Exposure Versus Contamination" on Page 28.

You should consider all patients to be contaminated, regardless of how they arrived to the ED, until they have been screened using a Geiger counter by the RSO. A lack of visible contamination (dust and debris) on a patient does not mean they are not contaminated. Patient care should proceed as usual and not be affected by the presumed presence of contamination. If staff concerns will affect care, consider that the National Council on Radiation Protection and Measurements has indicated that a skin contamination level measured at 1,000 counts per minute (cpm) corresponds to a skin dose of high-energy beta rays equivalent to 1.65 millirem (mrem) per hour.[1] If not decontaminated, the total dose in 24 hours would equal 40 mrem, which is considered to be of no health consequence. Assuming proportionality, 10,000 cpm would correspond to 16.5 mrem per hour and a total dose in 24 hours of about 400 mrem (0.4 rem) to the skin. The annual occupational dose limit to the skin is 50 rem (roentgen equivalent man), or more than 100 times greater. Most contamination can be eliminated by removing contaminated clothing, which can be rapidly performed if contamination levels and the concerns of emergency room staff warrant it.

After emergency room procedures are completed, do not delay moving patients to surgical or radiological suites or other studies because of concerns over the spread of low levels of contamination — contamination can be cleaned up.

"ED PREPSS"

Contact the RSO for the following equipment and expertise (or "ED PREPSS," a useful mnemonic):

- **Experts in radiation monitoring:** Locate radiation experts (the RSO or medical physicist staff).

[1] *Population Monitoring and Radionuclide Decorporation Following a Radiological or Nuclear Incident.* National Council on Radiation Protection and Measurements: NCRP Report No. 166; 2010. https://ncrponline.org/shop/reports/report-no-166-population-monitoring-and-radionuclide-decorporation-following-a-radiological-or-nuclear-incident/

- **Equipment:** Locate appropriate radiation survey equipment. To determine if contamination is present, use Geiger counters and report results in units of cpm.
- **Dosimeters:** Distribute personal passive radiation dosimeters to ED staff.
- **Personal protective equipment (PPE):** Begin standard PPE precautions, including putting on two pairs of gloves as well as a gown and mask. You should change outer gloves frequently as well as gloves and gowns if you find contamination on them by radiation survey. To learn how to put on and remove PPE, read "PPE Donning and Doffing Guidance" on Page 33.
- **Radiation control areas:** Designate public and treatment areas for triage. Place signs to alert staff these areas are radioactively contaminated.
- **Protect:** If there is time and it is feasible, protect the emergency room floor by taping down an impermeable floor covering. If this is not possible, then when personnel leave the emergency room, shoe coverings (such as booties) should be removed and placed in radioactive waste containers.
- **Surge:** Recruit staff from other hospital areas. Give them PPE and a dosimeter.
- **Survey:** The RSO or RSO staff should, when feasible without disrupting ED operations, repeatedly survey ED patients, ED surfaces (floors) and the PPE that staff are wearing.

Note: For a complete list regarding facility preparation, read "Preparing the ED for Patients Who Are Radiologically Contaminated Checklist" on Page 30.

Injury Patterns of Patients From an Explosive Radiological Incident

ED physicians should expect wounds to be contaminated with radioactive material. A radiological survey, no matter how cursory, should be performed as part of wound care.

Site Characteristics

- Dust and debris containing radioactive compounds are spewed up and outward from the detonation point. Imagine squeezing an open talc container, causing powder to be discharged up and around.
- Airborne material settles on outdoor surfaces, people and everything else in the immediate vicinity, resulting in a radioactively contaminated area surrounding the RDD.
- The radioactive compounds included in the RDD are the only source of radiation. Contamination may be carried farther by the wind as a plume that disperses in about 15 minutes.

Casualty Characteristics[2]

Effect	Impact	Radiological Impact on Typical Injuries
Primary	Injury from a highly pressurized blast wave that moves through the patient's body and organs	• Primary blast injury and tympanic membrane rupture • No specific radiological component to injuries
Secondary	Injury from a blast wave that drives explosion debris, such as shrapnel, into the patient	• **Penetrating injuries:** Explosion debris containing radioactive material contaminates the patient's skin and wounds. • **Multiple fragmentation wounds:** Highly radioactive embedded fragments will increase the patient's total exposure dose. • Concussion
Tertiary	Injury caused to the patient by propelling them into the air	• Blunt trauma • External radiological contamination
Quaternary	Heat or combustion fumes	• Burns • Inhalation injury
Quinary	Radioactive additives	• Cutaneous radiation burns • ARS • Internal contamination • External contamination

As in any other emergency, addressing the most immediate, life-threatening conditions is paramount. The treatment priorities, in order, are:

1. Ensure the safety of emergency responders.
2. Evaluate and treat life-threatening injuries before decontaminating the patient.

Patients who have experienced critical trauma and are radioactively contaminated should be treated in areas with ample space and the equipment appropriate for the level of care:

- Accumulated radioactivity on a contaminated piece of medical equipment is expected to be low.
- Once the patient has been transferred to another part of the ED, the emergency room and its equipment will need to be surveyed with a radiation detector for radioactive contamination by the RSO and RSO staff.
  - If the emergency room is contaminated, the equipment should be cleaned and resurveyed before being reused. This can be done under the direction of or directly by the RSO and RSO staff.

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[2]Rump A, Stricklin D, Lamkowski A, Eder S, Abend M, Port M. The incorporation of radionuclides after wounding by a "dirty bomb": The impact of time for decorporation efficacy and a model for cases of disseminated fragmentation wounds. *Adv Wound Care*. 2017;6(1):1-9. doi:10.1089/wound.2016.0693

Traumatic Injury Versus Radiation Injury

Fatalities and injuries will most likely be caused by the explosive forces of the RDD, not by radiation. These injuries and trauma may be life-threatening. Therefore, the rule is to treat these injuries before consideration is given to radioactive contamination or radiation exposure. Patients who were close to the detonation point are likely to have higher degrees of trauma. They are also at greater risk of being radioactively contaminated and acquiring a radiation dose.

Radioactive Contamination: Fixed Versus Loose Contamination

- Decontamination removes loose contamination but not fixed contamination. Fixed contamination is difficult to remove because it is either embedded in the skin or has a chemical affinity for the skin. There is a chance that some radioactive materials can be transdermal. Natural sloughing of skin cells removes fixed contamination over the course of two weeks.
- Radiological decontamination can be performed using warm water and mild soap to gently wash the skin.
  - Hair should be shampooed, but hair conditioner should not be used.
  - Dry decontamination can mean to remove outer garments and/or use Masslinn wipes to remove loose contamination from the skin.
- It is safe to work with patients who are radiologically contaminated if precautions are taken. However, ED staff may be exposed to a hot fragment embedded in a patient's clothes or body or to external contamination so dense it creates a possible risk to providers working closely to the patient.
- Radiation survey measurements are the only way to determine contamination levels and should be performed by experienced staff, such as the RSO or RSO staff.

Goals for Decontamination in a Non-Mass-Casualty Incident

- The objective is to achieve counts of less than 1,000 cpm.[3]
- If the radioactivity count rate remains higher than 1,000 cpm following two decontamination attempts, consider the contamination to be fixed or possibly internal. There is no need to continue external decontamination efforts after two decontamination attempts.

Goals for Decontamination in a Mass Casualty Incident

If no specific target levels are cited, perform decontamination procedures twice before surveying. Even if there is no decrease in the radioactivity count rate, move on to the next patient. To accommodate many casualties, it is possible to increase the contamination limits as shown in the flowchart on Page 10.

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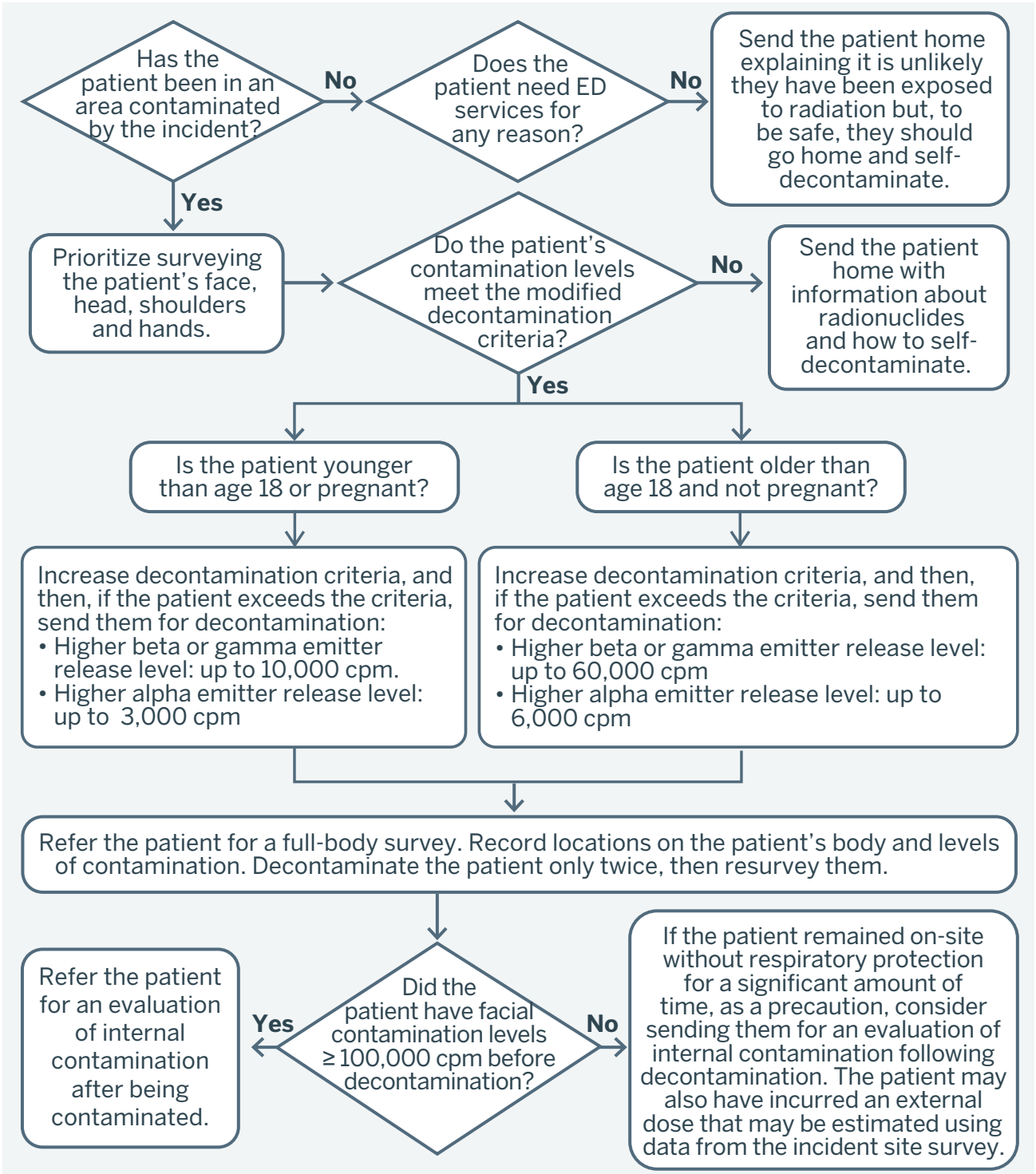
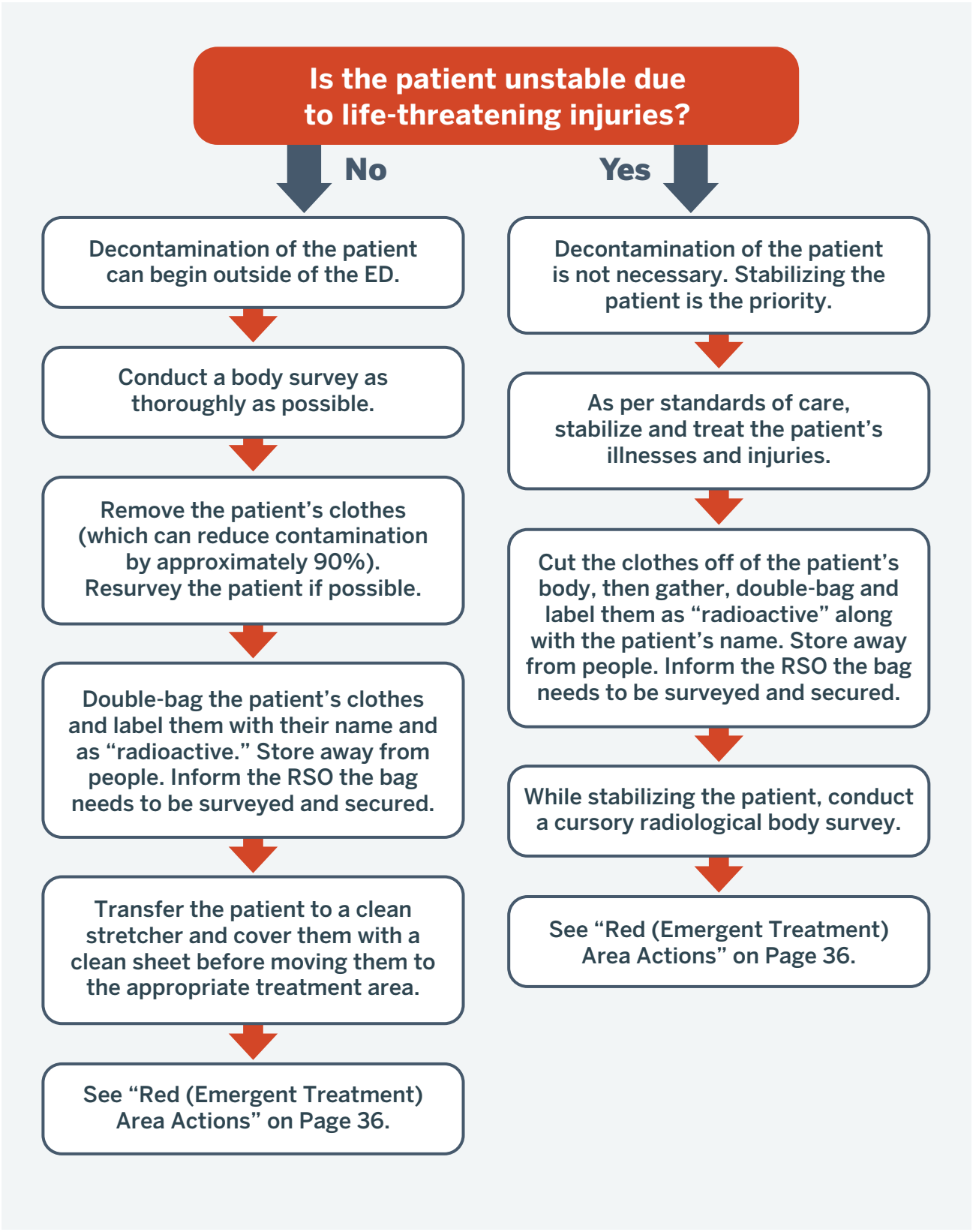
[3]*Handbook for Responding to a Radiological Dispersal Device: First Responder's Guide – The First 12 Hours*. Conference of Radiation Control Program Directors Inc.: CRCPD Publication 06-6; 2006. **https://tools.niehs.nih.gov/wetp/public/hasl_get_blob.cfm?ID=6229**

Modifying Decontamination Guidelines in a Mass Casualty Event[4]

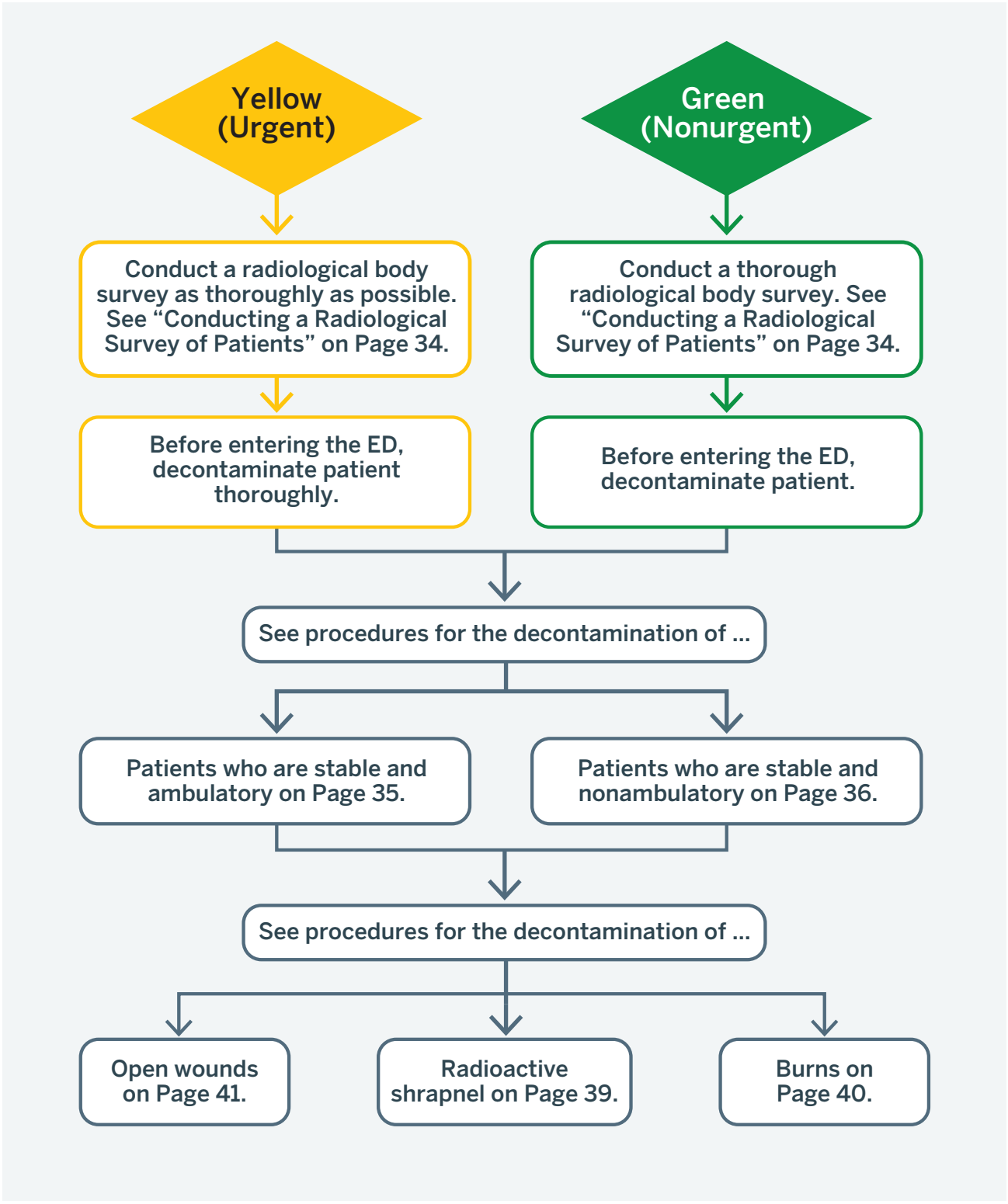


[4]The modified release criteria for gamma emitters are sourced from the Conference of Radiation Control Program Directors Inc. *Handbook for Responding to a Radiological Dispersal Device: First Responder's Guide – The First 12 Hours* (see previous citation). The modified release criteria for beta and alpha emitters are sourced from the CDC's *Population Monitoring in Radiation Emergencies: A Guide for State and Local Public Health Planners,* 2nd Edition (2014; **https://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf**), which references the International Atomic Energy Agency's General Safety Guide No. GSG-2 (2011).

Decontamination and Body Survey Algorithm by START Victim Classification Red Tag



Decontamination and Body Survey Algorithm by START Victim Classification Yellow and Green Tags



For more details, see "Red (Emergent Treatment) Area Actions" on Page 36.

Medical Management, Including Specialized Decontamination and Injury Care

Does the patient need to be decontaminated?
If so, see the specialized decontamination procedures for localized skin area, body cavities, eyes and body hair on pages 40 to 44.

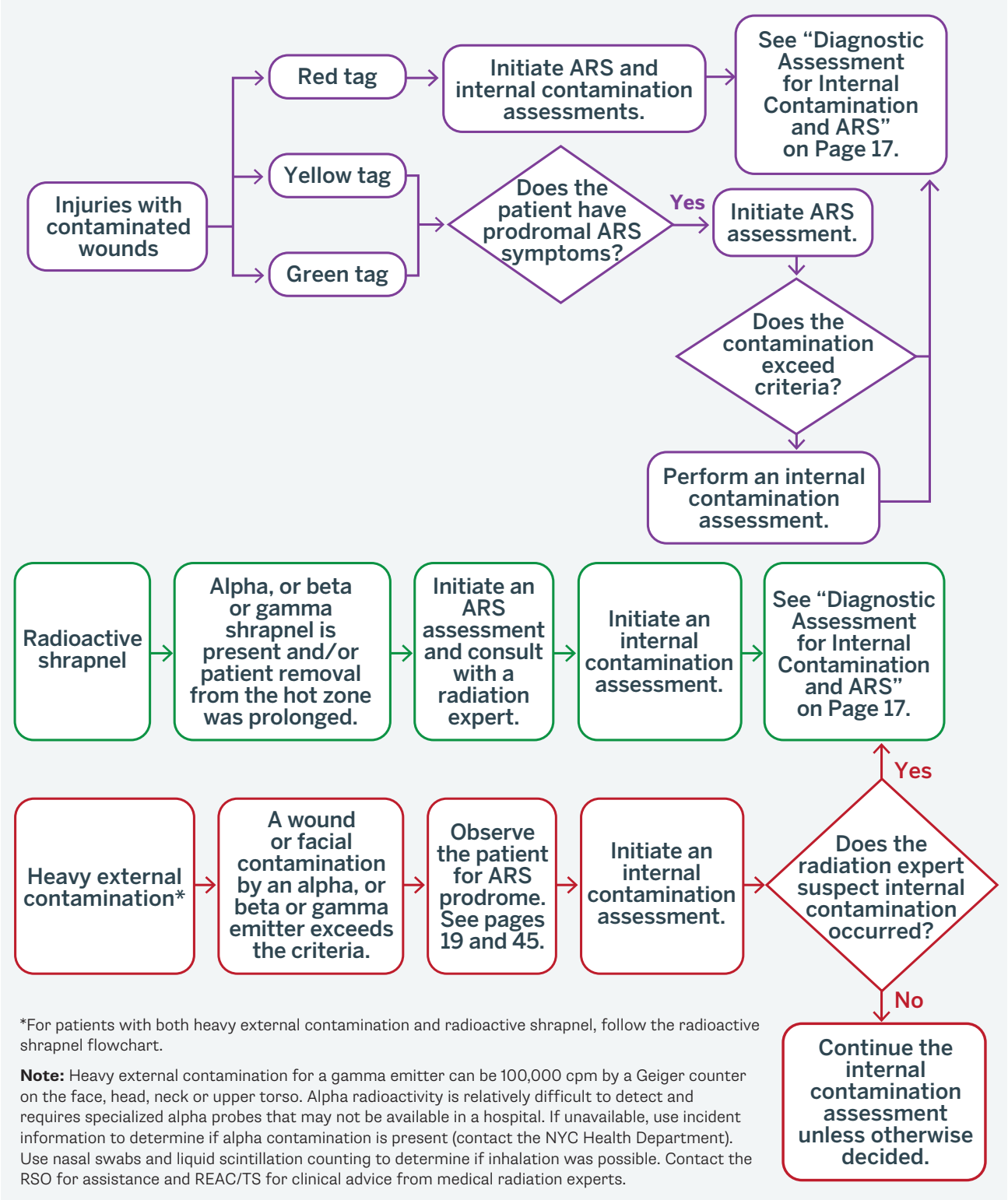
Does the patient have ARS?
If so, see “Diagnostic Assessment for Internal Contamination and ARS” on Page 17.

Is the patient pregnant?
If so, see “Pregnancy Considerations in a Radiological Emergency” on Page 26.

Does the patient need treatment for injuries or wounds?
If so, see the management procedures for contaminated open wounds, radioactive shrapnel and burns on pages 39 to 41.

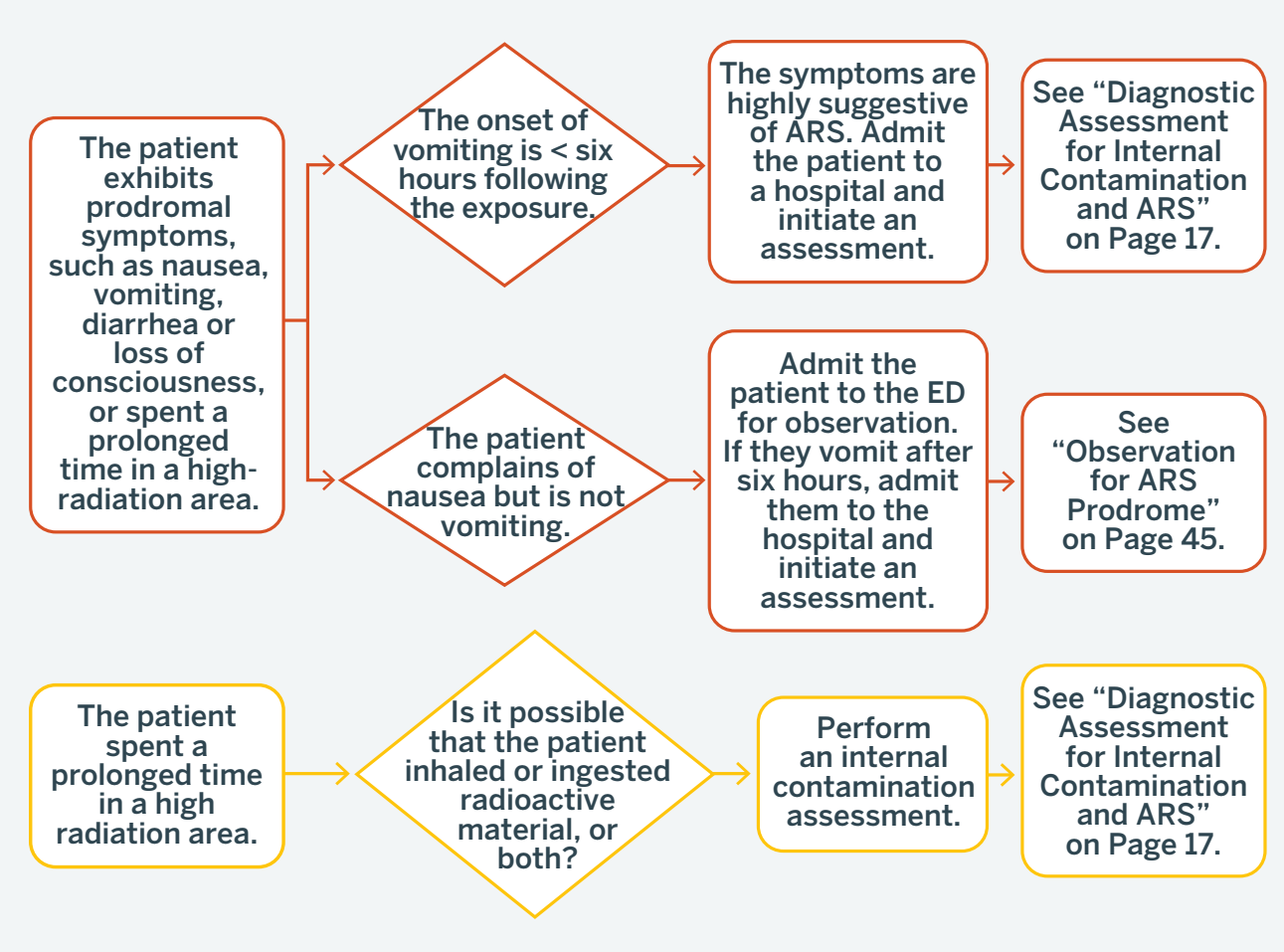
Does the patient need surgery?
If so, see “Surgical Considerations for Patients Suspected to Have ARS or High External Contamination” on Page 24.

Physical Findings and Patient's History Suggestive of Internal Contamination and ARS in Patients Treated in the ED



*For patients with both heavy external contamination and radioactive shrapnel, follow the radioactive shrapnel flowchart.

Note: Heavy external contamination for a gamma emitter can be 100,000 cpm by a Geiger counter on the face, head, neck or upper torso. Alpha radioactivity is relatively difficult to detect and requires specialized alpha probes that may not be available in a hospital. If unavailable, use incident information to determine if alpha contamination is present (contact the NYC Health Department). Use nasal swabs and liquid scintillation counting to determine if inhalation was possible. Contact the RSO for assistance and REAC/TS for clinical advice from medical radiation experts.



For more details, see "Yellow (Urgent Treatment) Area Actions" on Page 37 and "Green (Minor or Noninjured Treatment) Area Actions" on Page 38.

Radiological Illness of Patients From an Explosive Radiological Incident

ARS[5]

In an RDD incident, ARS is very unlikely to occur, as radiation doses of 1 gray (Gy), which equals 100 rad, are required to initiate ARS. However, since ARS should never be ruled out, the following information is provided.

ARS consists of four stages:

- **Prodrome:** Nausea or vomiting, which begins in minutes to days and can last one hour to multiple days.
- **Latent phase:** Symptoms abate; can last from minutes to several days.
- **Manifest illness:** The overt constellation of ARS signs and symptoms depends on the dose and its effects on major organ systems (for example, bone marrow depression, denuding of the intestine, cardiovascular collapse and coma). This stage can last for months.
- **Recovery or death:** LD_{50}/60 (lethal dose)[6] is approximately 600 rad with medical intervention and approximately 450 rad without. LD_{100} equals 10 Gy.

ARS is traditionally described in subsyndromes:

- **Hematopoietic:** Loss of stem cells in bone marrow
- **Gastrointestinal:** Denuding of the gut
- **Cardiovascular and central nervous systems:** Shock and coma

When the exposure is significant, the end stages of ARS are characterized by multiple organ failure.

Internal Contamination

- Radioisotopes can be internalized and continuously expose the body to radiation. If the internal organ exposure is high enough, ARS may develop. Radioisotopes can be eliminated naturally over time, but exposures can last decades and ultimately result in tissue damage. Elimination can be hastened with chelation. Significant exposures are also associated with increased risk of cancer later in life.
- Limited treatment with medical countermeasures is available (read “Internal Contamination Therapy Recommendations in the U.S. for Radionuclides of Concern” on Page 47).

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[5]Centers for Disease Control and Prevention. A brochure for physicians: Acute radiation syndrome. Accessed June 10, 2024. **https://www.cdc.gov/radiation-emergencies/media/pdfs/ARS.pdf**

[6]The dose that will kill 50% of the exposed population within 60 days of exposure. Note the difference with and without medical intervention.

Cutaneous Syndrome

Gamma burns affect the skin and underlying tissues (such as soft tissues, bone and vascular), resulting in injuries that can be very difficult to treat. Beta radiation burns do not go deeper than the basilar membrane.

Diagnostic Assessment for Internal Contamination and ARS

Estimating the radiation dose any patient received will be difficult. The patient's proximity to the radiation field, exposure rate at the patient's location and time spent there will be largely unknown. It may be possible to determine a dose from radioactivity that entered the body. That result will not reveal the radiation dose acquired from sources external to the body, including contamination at the site or on clothing or the skin. Estimating a dose from ARS symptoms may be possible — see "Assessment for ARS" on Page 18.

Assessment for Internal Contamination

Nasal Swab

If the patient is seen within one hour, collect samples from each nostril and submit them for a radiation count to determine if contamination is present versus background and therefore possibly inhaled.

Urine Bioassay for Radioactivity

1. Collect 70 milliliters (mL) of urine for testing at the CDC (see "CDC Specimen Collection for Bioassay of Internal Contamination" on Page 47).
2. Begin a 24-hour urine collection.
3. Consult with the NYC Health Department about shipping clinical samples to the CDC for radioisotope testing.
4. Consult with REAC/TS. Determine if further urine sampling is warranted. Bioassay may be required to be repeated for weeks or months to determine an estimated dose if it is confirmed that significant internal contamination has occurred.
5. The CDC will require the identity of the radionuclide(s).

Note: A bioassay analysis by the CDC will not be rapid. See "Nasal Swabs: Uptake by Inhalation" on Page 43 for a test that infers inhalation and may be possible to perform in-house by the RSO.

Assessment for ARS

Enlist aid from:

- REAC/TS, the CDC, the NYC Health Department and the New York State Department of Health (NYSDOH) to help estimate the patient radiation dose and to diagnose and treat ARS
- A hospital hematologist or intensivist, radiation oncologist, health or medical physicist, or infectious disease specialist

Begin serial complete blood counts (CBCs) with differential every two hours during the first eight to 12 hours following exposure, then every four to six hours for the next 48 hours. Track if absolute lymphocyte, white blood cell (WBC) and platelet counts decrease.

Precisely record all clinical symptoms:

- Record nausea, emesis, diarrhea, itching, and reddening or blistering of the skin particularly.
- Be sure to include the time of onset.
  - Time to emesis can be indicative of the severity of the radiation dose.
- Compare admission serum amylase level to the one obtained at 24 hours.

See the following tables for more details on the assessment for ARS:

Multiparameter Exposure Dose Guide at 24 Hours[7]

Dose	Prodromal Symptoms (Time to Emesis)		Bone Marrow Effects	Salivary Gland Effects
Gy	Percent Emesis	Median Onset of Emesis (in Hours)	Percent of Normal Absolute Lymphocyte Count in the First 24 Hours	Relative Increase in Serum Amylase (Day 1)
0	Psychogenic	Not applicable (N/A)	100	1
1	19	N/A	88	2
2	35	4.6	78	4
3	54	2.6	69	6
4	72	1.7	60	10
5	86	1.3	53	13
6	90 to 100	1	Less than (<) 47	Greater than (>) 15

*1 Gy = 100 rad

[7]*Multiservice Tactics, Techniques, and Procedures for Treatment of Nuclear and Radiological Casualties*. U.S. Army, Marine Corps, Navy and Air Force; 2014. Accessed June 10, 2024. **https://remm.hhs.gov/ATP_4-02_83_Treatment_Rad_May_2014.pdf**

ARS Signs and Symptoms[8]

Feature or Illness	Effects of Whole Body Absorbed Dose From External Radiation or Internal Absorption, by Dose Range in Rad (Gy)*				
	0 to 100 rad (0 to 1 Gy)	100 to 200 rad (1 to 2 Gy)	200 to 600 rad (2 to 6 Gy)	600 to 800 rad (6 to 8 Gy)	> 800 rad (> 8 Gy)
Nausea or vomiting	None†	5% to 50%	50% to 100%	75% to 100%	90% to 100%
Time of onset		Three to six hours	Two to four hours	One to two hours	< one hour
Duration		< 24 hours	< 24 hours	< 48 hours	< 48 hours
Lymphocyte count	Unaffected	Minimally decreased	< 1,000 at 24 hours	< 500 at 24 hours	Decreases within hours
Central nervous system function	No impairment	No impairment	Cognitive impairment for six to 20 hours	Cognitive impairment for > 20 hours	Rapid incapacitation
Mortality	None	Minimal	Low with aggressive therapy‡	High	Very high (significant neurological symptoms indicate lethal dose)

*The percentage of people receiving whole body doses within a few hours who are expected to experience acute health effects.
†A small number of people who have been exposed may experience symptoms such as nausea and emesis at doses between 50 and 100 rad (0.5 and 1 Gy).
‡The $LD_{50}/60$ is the lethal dose that produces fatalities in 50% of the population who received that dose. This dose is estimated to be between 320 and 450 rad (3.2 and 4.5 Gy) with no medical intervention.

Note: For a total body dose < 2 Gy or 200 rem:

- Prodrome: 10% to 50% of patients will have an onset of vomiting two hours after exposure. Patients with < 0.75 Gy will likely not experience nausea and vomiting.
- Outpatient management may be appropriate for exposure of ≤ 2 Gy if the patient does not have significant concurrent chronic illness, especially if they were not immunocompromised prior to exposure.

[8]*Medical Management of Radiological Casualties: Handbook*. 2nd ed. Armed Forces Radiobiology Research Institute; 2003. **https://apps.dtic.mil/sti/pdfs/ADA415842.pdf**

Treatment for ARS, Internal Contamination and Cutaneous Radiological Injury

Early Management of ARS

An ED physician should be prepared to:

- Order the administration of:
  - Antibiotic, antiviral and antifungal agents
  - Early cytokine therapy
    - Filgrastim (Neupogen), pegfilgrastim (Neulasta) and sargramostim (Leukine) should be used for the hematopoietic subsyndrome of ARS. These stimulate the production of white blood cells to decrease neutropenic nadir and duration. For more details, visit **remm.hhs.gov**.
  - 5-hydroxytryptamine or serotonin antagonists to treat nausea
- Perform early wound closure (see "Managing Open Wounds" on Page 41)
  - Usual standards of care for wound closures are applicable.

Enlist an infection control officer to institute the following:

- Barrier isolation
- Reverse isolation for patients with whole body doses > 2 to 3 Gy
- Strict environmental control, including isolation, handwashing, surgical scrubs and masks for staff, and possibly laminar flow room ventilation

Local Radiological Cutaneous Injury Treatment

- If burns are immediately apparent, the injury may be a combination of thermal and radiation burns, which develop more slowly.
- If a patient has significant thermal burns, treatment for them takes precedence over radiological injuries. Manage the burns by applying standards of care.
- If burns are superficial and small, gently cleanse as per the thermal burn protocol and cover with a sterile dressing.
- Administer topical class II to III steroids, topical antibiotics and topical antihistamines to radiation burns and blisters.[9]
- Take photos and consult with REAC/TS for further wound care.

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[9]Dainiak N. Medical management of acute radiation syndrome and associated infections in a high-casualty incident. *J Radiat Res*. 2018;59(Suppl 2):ii54-ii64. doi:10.1093/jrr/rry004

Internal Contamination Management

- If ingestion[10] is suspected, give the patient aluminum hydroxide or magnesium carbonate antacids orally to reduce gastrointestinal absorption. If strontium was identified as the radioisotope involved in the RDD, give the patient aluminum-containing antacids. Gastric lavage can be considered if within two hours of ingestion. Only use if there was a large intake of radioactivity that poses a significant health threat.
- If inhalation of a large amount of radioactivity is suspected with the likelihood of deterministic effects, consider lung lavage.
- As an isotope decays, it will expose tissues to radiation until it decays into a nonradioactive isotope or is eliminated from the body.
- Decorporation (chelation) treatment can increase the speed of elimination from the body.
  - Estimates of isotope body burdens and associated radiation dose may take days to complete.
  - Since treatment efficacy is improved the earlier decorporation treatment is initiated, administer countermeasures before body dose levels are known.
- There are a few countermeasures for specific radioisotopes that are available through the government. Discuss the case with the NYC Health Department to obtain the appropriate countermeasure.
  - **Prussian blue:** Binds with radioactive cesium in the gut, which prevents reabsorption of the radioactive cesium.
  - **DTPA:** Binds plutonium, americium and curium in the blood, which enhances excretion through the kidneys.
  - **Potassium iodide:** Saturates the thyroid, which blocks receptors, decreasing the uptake of radioactive iodine that binds to the thyroid.
    - Radioactive iodine is usually released as the result of a significant nuclear power plant accident. It can be but is not usually associated with use in an RDD. Potassium iodide is most effective when issued before iodine is released and therefore not very applicable to a no-notice event like an RDD. However, even post-incident dosages can be partially effective.

[10]Koening KL, Goans RE, Hatchett RJ, et al. Medical treatment of radiological casualties: Current concepts. *Ann Emerg Med*. 2005;45(6):643-652. doi:10.1016/j.annemergmed.2005.01.020

Prioritizing Patients With Potential Radiation Exposure Dose for Treatment

Patients who were closest to the detonation point will likely be the most injured and heavily contaminated. There is also a chance that these patients' internal exposure will be higher than those who were farther away, as they may have inhaled, ingested or absorbed radioactive material through contaminated wounds. These amounts will be unknown, but all three modes of exposure will contribute to the total radiation dose of a patient. Some patients may have been exposed to higher radiation shrapnel before they could be removed from the area.

Radiation sensitivity is inversely related to age, so children should be considered a priority. This also applies to pregnant people (as radiation sensitivity of the fetus is greater in the early weeks of pregnancy).

Prioritized List of People for Bioassays or Radiological Countermeasures

Highest priority	People who have serious or critical injuries (likely to be admitted)	• Open wounds • Heavy external contamination • Prolonged extraction time, which increases irradiation of the patient • Inhalation and ingestion of contamination, which increases internal contamination
Second-highest priority	People who have moderate or minor injuries (unlikely to be admitted)	• Open wounds • Possible internal contamination from inhalation and ingestion • Possible irradiation
Third-highest priority	No injuries but external contamination detected on face	• Possible internal contamination from inhalation and ingestion • Possible irradiation
Fourth-highest priority	Children and pregnant people without injuries, illness or external contamination	Increased sensitivity to radiation (particularly younger children and fetuses)
Fifth-highest priority	All other people who do not have injuries, illness or external contamination	Redirect to NYC Community Reception Centers.

Disposition Guidance for ED Patients

Patients who are pregnant and pediatric patients younger than age 18 should have priority for resources. For more details, see "Pregnancy Considerations in a Radiological Emergency" on Page 26. ED staff should notify the NYC Health Department and the Office of the Chief Medical Examiner about incident-related admissions, transfers and expirations.

Following Decontamination

Patient Condition	Guidance
Shows minimal or no contamination and was distant from the detonation point	**Release the patient to their home.** • Counsel the patient that the health effects from their exposure to radiation should be minimal. • Follow up with the patient's primary care physician (PCP). • Offer the patient mental health counseling.
Shows minimal residual contamination and was slightly closer to the detonation point	**Release the patient to their home with discharge instructions.**[11] • Tell the patient to collect a 24-hour urine sample. Provide a container and instructions. The container may be returned to the hospital or the NYC Health Department for shipment to the CDC.[12] See "Laboratory Information for Radiation Emergencies" on the CDC website. • Instruct the patient to return to the ED if they vomit or bleed. • Follow up with the patient's PCP 24 hours and three to five days after they are discharged. – Instruct the patient's PCP to obtain a CBC with differential and perform a wound check and skin exam.
Shows residual contamination and was in the proximity of the detonation point (exposure may need to be investigated)	**Limited emergency room observation of the patient — rule out ARS.** • See "Observation for ARS Prodrome" on Page 45. • Obtain two CBCs with differentials four to six hours apart. • Collect a 24-hour urine sample. If the patient is not admitted, provide a container and instructions for the patient to collect it. The patient must return the sample to the hospital or the NYC Health Department for shipment to the CDC.[12] See "Laboratory Information for Radiation Emergencies" on the CDC website. • Manage open wounds (see "Managing Open Wounds" on Page 41). • Consider medical countermeasures for internal contamination by isotope, if available, in consultation with the NYC Health Department.

[11]See a sample discharge letter template on Page 48.
[12]Results from the CDC will not be rapid. It is recommended to contact the CDC to discuss the current laboratory capacity and time for results to be obtained.

To be admitted (if suspected of internal contamination, external exposure or both)	**Admit the patient.** • Begin internal contamination and ARS workup (see "Diagnostic Assessment for Internal Contamination and ARS" on Page 17). • If surgery is needed due to injury, see "Surgical Considerations for Patients Suspected to Have ARS or High External Contamination" below on this page. • Care for wounds (see "Managing Open Wounds" on Page 41). • Consult with a hematologist or hospitalist at the facility for ARS management, REAC/TS for treatment and the CDC for radioactivity analysis of urine. • Notify the NYC Health Department.
Deceased	**Send the patient to the morgue.** • Notify the NYC Health Department and the Office of the Chief Medical Examiner. • Read REMM's guidance on management of the deceased (available at **remm.hhs.gov/deceased.htm**) and handling decedents contaminated with radioactive materials (available at **remm.hhs.gov/radiation-decedent-guidelines.pdf**).

Surgical Considerations for Patients Suspected to Have ARS or High External Contamination

Although radioactive contamination is likely to be low, it is best to have a survey done while triaging patients. Some radionuclides, such as cobalt-60 and iridium-192 (both of which are gamma radiation emitters), can fragment, resulting in shrapnel. The shrapnel from these radioisotopes can result in a very high radiation dose.

For patients who need surgery due to radioactive shrapnel or high external contamination:

- Treat all life-threatening injuries immediately, following current standards of care. Any radioactive contamination or radiation injuries are secondary.
  - If radiation burns are suspected, avoid central (parenteral) access in the area of the burns, if possible.
- Send a CBC with differential as soon as possible. Obtain an absolute lymphocyte count.
  - Include serum amylase with routine clinical samples.
- Type and crossmatch for blood products, if needed.[13]

[13]Dainiak N. Medical management of acute radiation syndrome and associated infections in a high-casualty incident. *J Radiat Res*. 2018;59(Suppl 2):ii54-ii64. doi:10.1093/jrr/rry004

  - Order irradiated blood products for all types of transfusion cells.
  - Order leukoreduction of all blood products, except white blood cells.
- Enlist the aid of a qualified health physicist or contact REAC/TS to obtain cursory total exposure dose.
- Initiate early use of granulocyte-stimulating cytokine therapy, if appropriate.
  - Consult with a hematologist or radiation medicine expert.
- Proceed with surgery within 48 hours of exposure if the patient is suspected to have 1 Gy (100 rad) or higher total exposure.

Potential Radiation Exposure to Surgical Staff

As an example of potential dose from contamination, consider the recommended total doses for emergency workers (incident responders). The U.S. Environmental Protection Agency's (EPA) Protective Action Guide Manual[14] recommends:

- 5 rem, the U.S. occupational dose limit, as one of the dose limitations for emergency workers. At this dose, there are no deterministic health effects and stochastic (cancer) effects are not observable.
- 25 rem as the maximum dose for voluntary emergency lifesaving activity for emergency workers. At this dose, the risk of deterministic health effects is minimal and stochastic health effects are a 1% increase in lifetime risk of cancer (the background cancer rate is approximately 42%).

Exposure Hours Necessary To Accumulate Dose Equal to Given EPA Guideline[15]

Radionuclide	Time To Reach Guideline at a Low Contamination Level (10 μCi/cm²)	Time To Reach Guideline at a High Contamination Level (100 μCi/cm²)	Guideline
Cesium-137	51 hours 250 hours	5 hours 25 hours	5 rem 25 rem
Americium-241	760 hours 3,800 hours	76 hours 380 hours	5 rem 25 rem
Cobalt-60	13 hours 64 hours	77 minutes 6 hours	5 rem 25 rem
Iridium-192	33 hours 170 hours	3 hours 17 hours	5 rem 25 rem

[14] *PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents.* U.S. Environmental Protection Agency: EPA-400/R-17/001; 2017. Available from **https://www.epa.gov/radiation/protective-action-guides-pags**

[15] Smith JM, Ansari A, Harper FT. Hospital management of mass radiological casualties: Reassessing exposures from contaminated victims of an exploded radiological dispersal device. *Health Phys*. 2005;89(5):513-520. doi:10.1097/01.hp.0000175444.30788.75

It is possible for ED personnel to acquire a dose, however small. Therefore, dosimeters should be issued and the RSO should be permitted to survey patient clothing (and, when feasible, patient skin and hair) to estimate μCi/cm^2 values for dose estimation. Doses may be minimized by removing contaminated clothing and rapidly treating the patient (minimizing the time spent in proximity to the contaminated patient).

Pregnancy Considerations in a Radiological Emergency

A mother's survival (maternal survival) is the most important factor for a fetus's survival (fetal survival).

- Due to the complicated clinical situation that a pregnant patient with traumatic injuries can present, radiography studies (such as X-rays) should be considered for treatment clarity, as the dose to the fetus is an acceptable risk when the mother's outcome will benefit.[16] The use of computerized tomography (CT) scans that expose the fetus to higher doses of radiation should be performed when other options are not available or acceptable and the survival of the mother or fetus is in question.
- Prenatal doses due to external radiation exposure are generally less than the total dose to the mother because the mother's abdominal and uterine walls provide shielding to the fetus.
- Prenatal doses due to internal contamination are also generally less than the total dose to the mother, except in situations involving isotopes affecting the thyroid (as the fetus' thyroid is actively growing and more sensitive to iodine than an adult's thyroid) or isotopes collecting in the maternal bladder (due to the bladder's proximity to the fetus).
  - For internal contamination countermeasures, pregnant patients should receive priority for treatment for the prevention of long-term effects (in other words, stochastic effects) in the fetus.
- With a prenatal dose below 5 rem, there is no significant risk of fetal malformation, reduced intelligence quotient (IQ) or other developmental abnormalities. Any pregnant patient with exposure or suspected exposure of 5 rem or greater should have specific counseling in consultation with a hospital health physicist and maternal-fetal specialist.

Radiation Dose to Fetus Following Maternal Radiography[16]

The following table shows typical estimated fetal doses from maternal radiography and computerized tomography (CT) scan procedures. They provide a perspective of the range of doses to the fetus that are safe (do not result in health effects):

Radiography Examination	Estimated Fetal Dose (rem)	CT Examination	Estimated Fetal Dose (rem)
Cervical spine (anteroposterior [AP], lateral)	< 0.0001	Head	0
Extremities	< 0.0001	Chest (routine)	0.002
Chest (posteroanterior, lateral)	0.0002	Chest (pulmonary embolism protocol)	0.02
Thoracic spine	0.0003	Abdomen	0.4
Abdominal (AP), 21 centimeter (cm) patient thickness	0.1	Abdomen and pelvis	2.5
Abdominal (AP), 33 cm patient thickness	0.3	CT angiography of the coronary arteries	0.01
Lumbar spine (AP, lateral)	0.1	CT angiography of the aorta	3.4

Maternal Exposure Dose and Effects on the Fetus

If there are any concerns about the exposure dose to the fetus, either from the incident or from proposed radiography studies, and the mother is not in a life-threatening situation, the health care provider can consult with a qualified and competent medical or hospital health physicist. A medical or health physicist can estimate the dose to the fetus and advise on diagnostic studies and treatment plans, especially before any decision concerning continuation of the pregnancy.

The fetus' gestational age and radiation dose are important determinants of potential noncancerous health effects. The following points[17] are of particular note:

- Before about two weeks gestation (or two weeks after conception), the health effect of concern from an exposure of ≥ 0.1 Gy, or 10 rad, is the death of the embryo.

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[16]Raptis CA, Mellnick VM, Raptis DA, et al. Imaging of trauma in the pregnant patient. *Radiographics*. 2014;34(3):748-763. doi:10.1148/rg.343135090

[17]Centers for Disease Control and Prevention. Radiation and pregnancy: A fact sheet for the public. Updated November 15, 2011. Accessed June 21, 2024. **https://www.emergency.cdc.gov/radiation/pdf/prenatal.pdf**

  - If the embryo survives, radiation-induced, noncancerous health effects are unlikely, no matter the radiation dose.
  - Since the embryo is made up of only a few cells, damage to one cell (the progenitor of many other cells) can cause the death of the embryo. The blastocyst will then fail to implant in the uterus.
  - Embryos that survive will exhibit few congenital abnormalities.
- In all stages of gestation, radiation-induced, noncancerous health effects are not detectable for fetal doses < about 0.05 Gy, or 5 rad.
  - Most researchers agree that a dose of less than 0.05 Gy represents no measurable noncancerous risk to the embryo or fetus at any stage of gestation.
  - Research on rodents suggests a small risk may exist for malformations, as well as effects on the central nervous system, in the 0.05 to 0.10 Gy (5 to 10 rad) range for some stages of gestation.
  - A practical threshold for congenital effects in the human embryo or fetus is most likely between 0.10 to 0.20 Gy (10 to 20 rad).
- From about 16 weeks into gestation to birth, radiation-induced, noncancerous health effects are unlikely at doses < about 0.50 Gy, or 50 rad.
  - Although some researchers suggest that a small possibility exists for impaired brain function from < 0.10 Gy (10 rad) in the 16-to-25-week stage of gestation, most researchers agree that after about 16 weeks into gestation, the threshold for congenital effects in the human embryo or fetus is approximately 0.50 to 0.70 Gy (50 to 70 rad).

For Your Safety: Radiation Exposure Versus Contamination

External Exposure (Irradiation)

- Radiation exposure occurs when all or part of the body absorbs penetrating ionizing radiation (gamma or X-rays) from an external radiation source (as shown in the illustration to the right).
- Exposure from an external source stops when a person leaves the area of the source, the source is shielded completely or the process causing exposure stops.

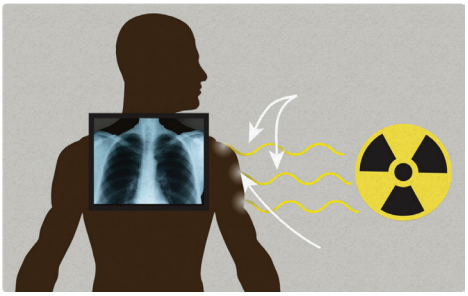

Image source: CDC

Irradiated patients do not emit radiation and radiation survey meters will not register when people have only had external exposure (similar to how a patient who has had a chest X-ray is not radioactive).

External Contamination (Radioactive Material on the Outside of the Body)

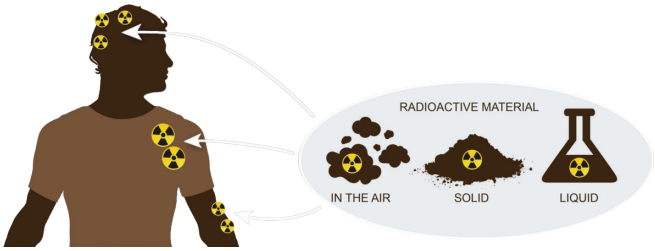

Image source: CDC

- External contamination is radioactive material (such as liquid, powder, metal fragments or dust) contaminating the body and clothes.
- External contamination may be removed by washing with water or taking off outer layers of clothing.
- Once the external contamination is removed from the body and taken elsewhere, it no longer has an effect on the body or emits radiation.
- Wearing standard precautions will prevent the spread of contamination to people and their clothes.

A person with radioactive gamma emitters (such as cesium or cobalt) on them can be radioactive (in other words, the contamination can emit radiation). Until the radioactive material is removed, a health care provider can be exposed, to however small an amount. Decontaminate patients arriving from the incident site before beginning treatment, unless their injuries are life-threatening.

Internal Exposure (Radioactive Material Inside the Body)

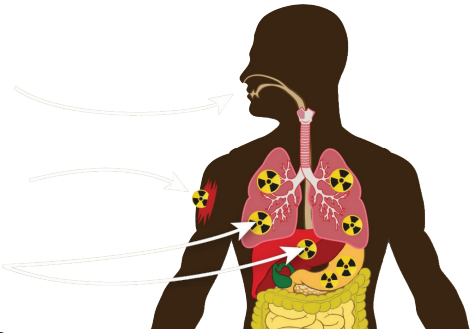

Image source: CDC

- Internal exposure is radioactive material (such as liquid, powder, metal fragments or dust) contaminating the inside of the body (as shown in the illustration to the right). Pathways include ingestion, inhalation, injection or absorption. A patient who has had nuclear medicine studies has internal contamination with a short-acting radioisotope.
- A patient with internal contamination may have contaminated bodily fluids. For example, patients that have received iodine-131 treatments will have iodine-131 in their sweat, blood and urine.
- Internal contamination may be a continuous source of radiation (exposure) if incorporated into the body and not rapidly removed.
- Certain treatments (countermeasures) exist for specific radioactive isotopes to lessen the amount of material in the body by blocking the absorption of the isotope, chelating the material or increasing its elimination.

Preparing the ED for Patients Who Are Radiologically Contaminated Checklist

What is the task?	Who was the task assigned to?	Has the task been completed?
Notify the RSO and other trained radiation response personnel.		
In the case of an explosive event, institute the facility's mass casualty plan.		
Set up a decontamination area as per the facility's decontamination plan.		
Set up donning and doffing areas and supply them with PPE.		
Make sure area radiation monitors work and are turned on.		
Distribute personal radiation dosimeters.		
Locate survey meters and check their batteries and calibration dates.		
Assign survey meters to staff responsible for radiation monitoring as per the facility's plan.		
Determine the background radiation level of the emergency room for comparison with readings of contamination. Use rooms adjacent to the emergency room if the patients who are contaminated have already entered.		
Set out multiple large, plastic-lined waste containers and label them as radioactive materials.		
Cordon off and restrict access to the emergency room and adjacent areas where contamination may have entered.		
Place signage to label areas that are potentially contaminated or have been shown to be contaminated by measurement (radiation areas).		

What is the task?	Who was the task assigned to?	Has the task been completed?
Cover the beds in emergent (red treatment) areas with one or two waterproof covers.		
Cover surfaces and large equipment (such as portable X-ray machines) in emergent (red treatment) areas with large sheets of plastic, if time allows.		
Cover the floor of entry to the ED and treatment areas, if time allows.		
Have a change of clothes for patients after they are decontaminated.		
Have sufficient waste containers for potentially contaminated clothing, dressings and other items. Remain in communication with the RSO.		
Move hospital workers who are pregnant to areas that will not manage patients who are potentially contaminated.		

Working Safely With Radiological Contamination

Working With Contaminated Patients

Don PPE, including a dosimeter:

- Wear a dosimeter on a lapel or the upper torso.
- Change outer gloves frequently and always after touching a patient and before moving to another patient.
- Maintain distance from any radioactive source, including patients who are radioactively contaminated. Working at an arm's length with patients who are radioactively contaminated will decrease your dose.
- Never handle radioactive materials with your bare hands. If you need to remove radioactive shrapnel, use extended forceps and place the material in a lead-lined container.
- Follow radiation safety instructions given to you by the RSO or a health or medical physicist.

Working Safely in a Radiologically Contaminated Space

- If the ED becomes contaminated, radiation levels will most likely be low and not present a significant health hazard to staff working in the space.
- The dose limit for health care workers is 5 rem per year. This is a regulatory limit and well within an exposure dose that will not have a significant health impact. It is very likely health care workers will have much lower exposure doses.
- In the unlikely event that high levels of radiation are encountered, non-health-care workers and visitors will have stricter total exposure dose limits than health care personnel and may have to vacate areas that health care workers can continue working in.
- Take actions to limit exposure doses (see "Preparing the ED for Patients Who Are Radiologically Contaminated Checklist" on Page 30).
- Designate radiation control areas where patients who are radiologically contaminated will be treated or held, and inform staff of the location of these areas and place signage designating the radiation control areas.
- In radiation control areas (or other areas with elevated readings of radioactive contamination), have the RSO, at their discretion, advise on hospital staff stay-time limits. Inform staff of stay-time limits, emphasizing that, while there is no need to avoid radiation control areas, staff can choose to limit their time in them. There may be other rules to follow, such as the doffing of PPE, if leaving a radioactively contaminated area for a uncontaminated area.
- Place patients who are radiologically contaminated in as few areas of the ED as possible (marking radiation control areas will help facilitate this). Treatment areas for patients who are radiologically contaminated could eventually become contaminated, so choose areas that will not have a large impact on the function of the ED while they are waiting to be cleaned, if possible.
- Minimize unnecessary time in radiation control areas, and when feasible, maximize the distance from known sources of radiation. Always keep the dose as low as reasonably achievable.
- Do not eat or drink in the radiation control areas. Staff should go to an area designated by the RSO to disrobe, wash their hands, and be surveyed prior to departure or eating. This is to prevent the accidental contamination of other areas or food and the possible ingestion of radioactive material.
- Have hospital personnel who are knowledgeable about radiation (such as the RSO) survey contaminated spaces, surfaces (such as floors, counters and sinks), patients and workers' PPE (including gloves and gowns).
- Designate an area to store radioactive waste away from where people are working or waiting. Contaminated materials must be discarded as radiation waste and not strictly as biological waste, red-label hazardous waste or general trash. Consult the RSO for proper radioactive waste management procedures.

Another concern will be the spread of contamination from the emergency room to corridors, elevators, treatment rooms or other areas of the hospital. The amounts of contamination can be limited.

- Patients should be transferred to gurneys at the boundaries of potentially contaminated areas to known uncontaminated areas.
- ED staff that are moving from a potentially contaminated area to a known uncontaminated area must remove PPE, including gloves, hairnets and, especially, shoe covers.
- All potentially contaminated PPE should be placed in radioactive waste containers following the policies of the RSO.

PPE Donning and Doffing Guidance

Donning PPE

Personnel working in radiation control areas should don the following Level C PPE:

- A radiation dosimeter
- A scrub suit and gown (cloth or paper) or Tyvek coveralls
- An air-purifying respirator with a P10 or high-efficiency particulate air filter that covers the entire face (for respiratory protection when working with patients who are radiologically contaminated)
  - This is not a requirement. An N95 respirator with a face shield and a head or hair covering (see the next bullet point) will suffice.
- A fit-tested N95 respirator with a face shield and head or hair covering (for respiratory protection when working with patients after they have been decontaminated)
- Two pairs of gloves (the inside pair of gloves should be under the arm cuff of the gown and secured with heavy tape, such as duct tape or chemical decontamination suit tape, and the outside pair of gloves should be easily removable)
- A head cover or bonnet
- Waterproof shoe covers
- Waterproof aprons or outer gowns (for staff using liquids for decontamination or who are at risk of getting splashed by liquids)

Remember to tape shut all open seams and cuffs using heavy, water-resistant tape, such as duct tape or chemical decontamination suit tape. Dosimeters should be attached to the outer garment and placed near the neck under the gown to avoid gross contamination.

Doffing PPE

Before exiting a radiation control area, personnel should begin doffing PPE at the control line (the border between the radiation control area and clean area):

1. Remove your outer pair of gloves, turning them inside out as you pull them off.
2. Give your dosimeter to the RSO or other assigned person.
3. Remove all the tape on your trouser cuffs and sleeves.
4. Remove your outer gown, turning it inside out while taking it off. Avoid shaking.
5. Remove your head cover and mask.
6. Remove your shoe cover from one foot and let the RSO or other assigned person monitor the shoe cover. If the shoe cover is clean, step over the control line, remove the other shoe cover and let the RSO or other assigned person monitor the shoe cover.
7. Remove and discard your inner pair of gloves.

Conducting a Radiological Survey of Patients

Surveyors should be trained on how to use radiological detection equipment.

- When using radiation detection equipment:
  - Initially survey the patient's face, hands and feet.
  - Continue to scan the patient's body if the survey results are positive.
- When performing a body survey:
  - Scan thoroughly (surveys should take five to eight minutes per patient).
  - Move slowly (no more than 2 inches per second).
  - Keep approximately 1 inch of distance between the probe and the surface of the patient's body.

Note: Although portable survey meters are relatively easy to use, they do require training and practice to use properly. This training should be incorporated into radiological response exercises and can be provided by the RSO.

Decontamination of Patients Who Are Stable and Ambulatory

Before reading this page, see "Decontamination and Body Survey Algorithm by START Victim Classification Yellow and Green Tags" on Page 12.

- Perform a pre-decontamination survey:
  - Prioritize the surveillance of the patient's head, neck, hands, feet and shoulders.
  - Mark the contaminated areas on the patient's body in cpm.
  - Send the patient to decontamination if the survey becomes too difficult to perform due to a surge of patients entering the ED or lack of available equipment.
    - This is important if the patient is obviously covered in high-risk debris from the detonation point.
- Remove contaminated clothing from the patient (this removes 75% to 90% of contamination):
  - Designate a holding area for contaminated clothing away from the patient care area (the RSO can provide a designated radioactive waste container).
  - Remove clothing carefully and avoid having clothing touch the patient's face as much as possible.
    - Avoid pulling clothing, such as T-shirts and sweaters, over the patient's head. Use trauma shears to cut them away instead. Place the clothing in a bag, then into a radioactive waste container.
  - Label all radioactive waste containers (such as bags, pails and drums) as "radioactive" and follow patient identification procedures. The RSO can provide the proper labels.
- Complete a basic decontamination wash:
  - Use copious amounts of tepid water and gentle soap.
  - Do not scrub the patient's skin, as it may cause small breaks in the skin, which can increase the chance of internal uptake.
  - Do not use hair conditioner, which can make it more difficult to remove radioactive material from the patient's hair.
  - Avoid water runoff from entering the patient's eyes, nose or mouth or any open wounds.
  - Radioactive "hot" particles (shrapnel) may need to be removed individually in treatment areas.
- Perform a post-decontamination survey, if feasible:
  - If a patient's radiation levels are still > 1,000 cpm, repeat the body decontamination process to reduce the amount of contamination on the patient.

- Do not decontaminate the patient if:
  - Their clinical status prevents them from receiving additional decontamination showers
  - Additional decontamination attempts fail to reduce their contamination count rates
  - They have already undergone two whole body decontamination attempts

Decontamination of Patients Who Are Stable and Nonambulatory

Before reading this page, see "Decontamination and Body Survey Algorithm by START Victim Classification Yellow and Green Tags" on Page 12.

- Remove all clothing and personal effects from the patient:
  - Avoid contaminating the patient's nose and mouth.
  - Cut the patient's clothing down from the center of their chest. Roll the patient's cut clothing away from their face and out from under them.
  - Store clothing someplace safe and label it as "radioactive."
- Consider labeling stretchers as "for decontamination only."
- Decontaminate prosthetics, ambulatory assistance devices and wheelchairs. Perform a post-decontamination survey to verify that decontamination was successful. Consult the RSO for assistance.
  - Return prosthetics, ambulatory assistance devices and wheelchairs to the patient if attempts at decontaminating them are successful.
  - If the patient's contamination count remains persistently > 1,000 cpm, it may be necessary to terminate further attempts and allow skin sloughing to gradually remove the contamination.

Red (Emergent Treatment) Area Actions

When outside the ED:

- Remove the patient's external clothing.
- Wrap the patient in a clean sheet.
- Transfer the patient to a clean stretcher before they enter the ED, bypassing the decontamination procedures for now.

When inside the red (emergent treatment) area:

- Continue resuscitation and perform decontamination simultaneously.
- Survey the patient during resuscitation.
- Stabilize the patient.

- If the patient is admitted, begin a workup for potential ARS:
  - Serial CBCs (every six hours for 48 hours)
  - Serum amylase
  - Human chorionic gonadotropin (to determine pregnancy status)
- Use the results of the CBC test to determine the patient's total lymphocyte count and lymphocyte depletion:
  - Begin a 24-hour urine collection for a possible bioassay, if requested by the NYC Health Department or recommended by REAC/TS. A facility to analyze the samples and report results will be needed. The CDC is a possibility, but turnaround times will likely exceed that needed for clinical decisions.
- Note the times and onset of prodromal symptoms, if they occur.
- Notify the NYC Health Department about the patient and request countermeasures, if needed.
- If internal contamination is suspected, the isotope is known and a countermeasure is available, administer or prescribe medication to patients for internal contamination based on public health guidance.

Yellow (Urgent Treatment) Area Actions

Before entering the yellow (urgent treatment) area, patients should go through the hospital's decontamination process.

When inside the yellow (urgent treatment) area:

- Treat the patient's injuries and illnesses.
- Obtain the first CBC.
- Determine the patient's risk of internal contamination.
- Observe the patient for up to six hours after the radiological incident for nausea or emesis.
- Obtain the second CBC test results four to six hours after the first.
- Use the tests results to determine the patient's total lymphocyte count and lymphocyte depletion.
- Obtain a urine sample for a bioassay analysis by the CDC for radioactivity, if requested by NYC Health Department or REAC/TS.
- If the patient is admitted, begin a workup for potential ARS:
  - Serial CBCs (every six hours for 48 hours)
  - Serum amylase
  - Human chorionic gonadotropin
- Use the results of the CBC test to determine the patient's total lymphocyte count and lymphocyte depletion.
- Begin a 24-hour urine collection for a possible bioassay, if requested by the NYC Health Department or REAC/TS.

- Note the times and onset of prodromal symptoms, if they occur.
- Notify the NYC Health Department about the patient and discuss countermeasures, if available.

Green (Minor or Noninjured Treatment) Area Actions

Before entering the green (minor or noninjured) treatment area, patients should go through the hospital's decontamination process.

When inside the green (minor or noninjured) treatment area:

- Treat the patient's minor injuries and illnesses.
- Determine the patient's risk of external exposure or internal contamination.
  - If the patient has a significant risk of external exposure or internal contamination:
    - Keep the patient in the ED for observation for four to six hours prior to discharge.
    - Notify the NYC Health Department about the patient and discuss countermeasures, if available.
  - If the patient does not have a significant risk of external exposure or internal contamination, discharge them to their home or another safe location.
  - Provide any lab results to the patient or their health care provider.
- Have the patient return to the ED if emesis, nausea, bleeding, or skin or hair changes occur.
  - Consider obtaining a CBC in 24 hours.
  - Consider performing another skin exam in 24 hours.
- The patient's primary provider should give them a follow-up exam with CBC.

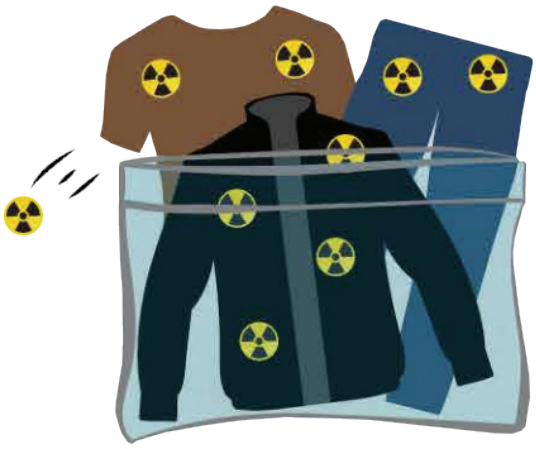

Image source: CDC

Removing Radioactive Shrapnel

Consider all open wounds contaminated until proven otherwise.

- Use an appropriate radiation survey meter to evaluate and monitor the medical management of radioactive shrapnel to protect the medical team. Consult with the RSO.
- Assume embedded foreign bodies will produce uptake (internal contamination).
- Cover the skin surrounding open wounds (with or without foreign bodies) with waterproof dressings or drapes to limit the spread of radioactivity by water runoff during wound irrigation and decontamination.
- Irrigate wounds gently with copious amounts of water or saline.
  - Multiple irrigation attempts are usually necessary.
  - Remove visible radioactive foreign bodies (such as metallic fragments or shrapnel) using forceps or water flosser.
  - While removing radioactive shrapnel, use long surgical instruments that maximize distance between the operator and shrapnel.
- The RSO should properly store removed foreign bodies and any instruments used to handle foreign bodies in shielded containers and label them as a radioactive. Keep in case the NYC Police Department or Federal Bureau of Investigation need these for forensic evaluation.
- Organize health care provider decontamination teams to minimize exposures to team members.
- Frequently monitor individual team member radiation doses.
- Frequently rotate teams and team members away from high radiation dose fields.
- If contamination levels remain high after primary decontamination attempts, consider conventional surgical debridement of wounds.
  - Obtain expert medical and health physics advice before the excision of vital tissue.
  - The RSO should properly store and label radioactive tissue that is surgically removed. All used surgical supplies must be labeled as radioactive and disposed of as radioactive waste unless needed for forensic evaluation. Surgical equipment may be decontaminated.
  - Cover decontaminated wounds with a waterproof dressing to prevent further contamination.
  - Decontaminate skin around wounds as thoroughly as possible before suturing or other treatment.
  - Decontaminate intact skin as described in “Localized Skin Decontamination” on Page 42.

Decontamination and Treatment of Burns

Patients presenting with burns are more likely to have thermal burns that are contaminated. Cutaneous radiation injury (CRI) can occur at doses as low as 2 Gy and is often seen with ARS (but not always).

- The extent of CRI depends on the magnitude of the dose and how deeply the radiation has penetrated.
- Unlike the skin lesions caused by chemical or thermal damage, the cutaneous injury caused by radiation exposure does not appear for hours to days following exposure.
- Thermal and chemical burns are visible on admission.
- The key treatment issues with CRI and thermal burns are pain and infection.

To decontaminate burns (chemical or thermal) with radioactive contamination:

- Rinse gently and cover.
- Treat contaminated burns like any other burn (they can be managed like an open wound).
- Exudates will trap most of the contamination.
- Contaminants will slough off with the burn eschar.

Follow the usual protocol for the treatment of burns. Consider consulting REAC/TS for more information about absorption of radionuclides through a burn.

Hairy Area Decontamination

Do not shave hair.

- Survey the area and record results.
- Wrap or position the patient to avoid the spread of contamination.
- Dry with clean uncontaminated towel.
- Resurvey the area.
- Repeat washing if contamination persists or until there is no further reduction in radioactive contamination count rate.

Managing Open Wounds

Consider all open wounds contaminated until proven otherwise.

- Assume significant wound contamination will produce uptake (internal contamination).
  - Attempt to prevent or minimize further uptake of radioactive material into the body.
- Cover skin surrounding open wounds (with or without foreign bodies) with waterproof dressings or drapes. This will limit the spread of radioactivity by water runoff during irrigation or decontamination.
- Irrigate wounds gently with copious amounts of saline or water.
- Monitor wounds with radiation survey meters before and after each irrigation attempt and record results.
  - Gently swab wounds with a sterile cotton-tipped applicator and survey the cotton tip for levels of radioactivity.
  - If monitoring wounds directly, remove contaminated drapes, dressings and other coverings before conducting survey.
- If contamination levels remain high after primary irrigation attempts, consider conventional surgical debridement of wounds.
  - Obtain expert medical and health physics advice before the excision of vital tissue.
  - The RSO should properly store and label radioactive tissue that is surgically removed. All used surgical supplies must be labeled as radioactive and disposed of as radioactive waste unless needed for forensic evaluation. Surgical equipment may be decontaminated.
- Cover decontaminated wounds with a waterproof dressing to prevent further contamination.
- Decontaminate skin around wounds as thoroughly as possible before suturing or performing other treatment.
- Decontaminate intact skin as described in “Localized Skin Decontamination” on Page 42.

Localized Skin Decontamination

- The goal of localized skin decontamination is to decrease external contamination to a level of ≤ 1,000 cpm.
  - Perform two decontamination cycles, if feasible, with a confirmatory radiation survey after each cycle.
  - Use tepid decontamination water.
  - Add mild soap (neutral pH) to water to emulsify and dissolve contamination.
  - Direct contaminated wastewater away from the patient rather than over the rest of the body.
- Use serial washcloths, gauze pads or surgical sponges to avoid recontamination.
- Stop localized decontamination efforts after two decontamination cycles[18] if:
  - The second radiation survey shows external contamination > 1,000 cpm
  - Additional external decontamination efforts do not further reduce contamination levels by more than 10%
- Attempts to remove all contamination may not be feasible or desirable.
  - Some radioactivity may be trapped in the outermost layer of skin (stratum corneum) and will remain until normal sloughing occurs (within 12 to 15 days).
  - Attempts at vigorous decontamination may result in loss of normal intact skin barrier and an increased risk of internal contamination.
  - Cover areas of residual radiation contamination with waterproof dressings or drapes to limit the spread of contamination to other body sites, the immediate environment and other people.
  - Treat focal hand contamination not removed after washing by promoting sweating, such as by putting the hand in a surgical glove for a few hours.
- Persistently elevated levels of external contamination after adequate decontamination may also be due to:
  - Internal contamination
  - Retained radioactive foreign bodies (radioactive shrapnel)
  - Contaminated wounds
  - Contaminated orifices

[18]The option to use Masslinn wipes is viable if there is a need to minimize decontamination water volumes. Masslinn wipes are not sterile. There is the possibility that they can contribute to skin breakage if used too vigorously.

Nasal Swabs: Uptake by Inhalation

- Uptake of radioactive material may be faster through body orifices and mucous membranes than intact skin.
  - Nasal swab use in a large mass casualty incident is likely not feasible due to the number of patients, transportation time to hospital and limited laboratory analysis capability.
  - Nasal swabs are unreliable after one hour post-inhalation of radioactivity due to normal mucociliary clearance.
- Nasal swabs can provide a crude estimate of the radioactivity deposited in the lung (combined activity at both nostrils may be approximately 5% of radioactivity deposited in the deep lung).[19]
- Nasal swab analysis for radioactivity is best determined by sensitive liquid scintillation counting rather than portable radiation detection equipment. Consult the RSO to perform proper liquid scintillation counting analysis.
- Using nasal swab information to manage patients requires collaboration between the RSO and clinical subject matter experts.
- Carefully assess that the body cavity is contaminated rather than the surrounding area.
- Perform wipe tests to assess orifice contamination:
  - Gently swab each naris with a separate sterile cotton-tipped applicator.
  - See RSO to perform a liquid scintillation counter analysis. The results are not quantitative unless the counter is calibrated for the identified radioisotope. Therefore, it will only indicate the presence of radioactivity compared with background.
  - Combine the results from both nostrils. If both are above background, it is indicative of inhalation but subject to significant overestimation or underestimation due to particle size, shape, chemistry, physical stability and patient inhalation patterns (for example, the patient may be an obligate mouth breather).
  - Activity above background at one nostril only may be indicative of contamination rather than inhalation (due to wiping of nose by contaminated hands).
  - Discuss results and next steps with internal dose specialists such as REAC/TS.

[19]National Council on Radiation Protection and Measurements. Management of persons contaminated with radionuclides. NCRP Report No. 161-I. 2008. **https://ncrponline.org/shop/reports/report-no-161-i-management-of-persons-contaminated-with-radionuclides-handbook/**

Decontamination of Body Cavities

Decontaminate contaminated body orifices before decontaminating intact skin but after decontaminating open wounds.

Radioactive analysis of irrigation fluid is difficult or impossible to do using handheld portable survey meters. Liquid scintillation counting is much more sensitive but time-consuming and requires experience to use properly. Consult with the RSO. It will be necessary to prolong decontamination over hours or perhaps days to accommodate the use of liquid scintillation counting analysis.

Ear Decontamination

- Ensure the integrity of tympanic membrane (TM) prior to decontamination.
- Use an ear syringe to rinse the external auditory canal, only if TM is intact.
- Sample collected irrigation fluid at frequent intervals for residual radioactivity (liquid scintillation counting will be necessary).
- Properly collect, store and label irrigation fluid for proper disposal.

Oral Cavity Decontamination

- Encourage toothbrushing with toothpaste and frequent mouth rinsing.
- Encourage gargling with a 3% hydrogen peroxide solution for pharyngeal contamination.
- Sample collected mouth fluid for residual radioactivity (liquid scintillation counting will be necessary).
- Properly collect, store and label irrigation fluid for proper disposal.

Eye Decontamination

- Use X-rays to rule out the presence of shrapnel in the globe of the eye.
- Irrigate eyes gently with copious amounts of saline or water, if corneal contamination is present and the globe is intact.
- Do not irrigate a ruptured globe.
- Direct irrigation stream from the inner canthus to the outer canthus to avoid contamination of the nasolacrimal duct.

- Collect the fluid used to irrigate the eyes. If possible:
  - Survey collected irrigation fluid at frequent intervals for residual radiation (liquid scintillation counting will be necessary).
  - Properly collect, store and label irrigation fluid for proper disposal.
- Observe for onset of conjunctivitis following decontamination.

Observation for ARS Prodrome

The goal of ED observation is to take sufficient time to evaluate patients who may have had significant radiation exposure and have a risk of developing ARS symptoms.

Observe patients for the following traumatic injuries that are indicative of potential radiation exposure due to proximity to the explosion:

External Truncal Injuries	Blast Injury to TM	Eye Injuries	Blunt Trauma	Thermal Burns
Penetrating truncal injuries	Eardrum rupture (hearing loss)	• Permanent visual loss • Minor trauma • Foreign bodies (including projectiles)	• Rupture or contusion of major air-containing organs • Solid organ injury	Skin burns

Also, observe patients who are being considered for discharge. If the patient or you can answer yes to any of the following questions, the patient may be at risk of internal contamination or significant exposure:

- Did they have an injury or illness due to the event?
- Were they a first responder without respiratory PPE? (If they are a first responder and are wearing a dosimeter, request that it be read out to acquire the total radiation dose.)
- Did they have a penetrating injury or contaminated wound with radioactive material?
- Did they have a prolonged extraction from the event, especially if they did not have respiratory protection during this time?
- Did they have prolonged transit time or spend prolonged time in the immediate area around the event (such as a bystander rescuing others), especially if they did not have respiratory protection during this time?
- Have they had any history of nausea, vomiting, fatigue or diarrhea within hours after the event?

- Was the patient heavily contaminated, with Geiger counter count rates nearly reaching or exceeding 100,000 counts per minute especially on the face, head, neck and upper torso?
- Did nasal swabs indicate radioactivity may have been inhaled?

In addition, contact the NYC Health Department for the following incident information:

- Have gamma-emitting radioisotopes been identified at the incident? (The penetrating radiation can irradiate internal organs.)
- Have alpha-emitting radioisotopes been identified at the incident? (Alpha particle radiation can deliver a very large dose to lung tissue if contamination is inhaled.)
- Are there areas at or around the incident with dose rates greater than 10 rad per hour?

If it is determined a patient requires further observation, begin with these steps:

1. Observe up to six hours after the event for nausea or vomiting.
2. Obtain two CBCs four to six hours apart.
3. Use results of CBCs to determine total lymphocyte count and lymphocyte depletion.
4. Obtain urine sample for potential radioactive bioassay, if requested by the NYC Health Department.
5. Consider beginning outpatient treatment for internal contamination based on history.
6. Contact the NYC Health Department about all patients being observed.
7. Contact REAC/TS to discuss patient status if diagnosis is indeterminate.

Discharge Considerations After a Radiological Incident

- Discharge the patient to their home. Provide any lab or radiation survey results.
  - The results of the contamination assessment should be clearly stated on the discharge instructions.
- Advise the patient to return to the ED if they experience vomiting, nausea or bleeding or there are changes to their skin or hair.
- Provide instructions for wound care or other injury-related illnesses.
- Consider obtaining a CBC with differential in 24 hours.
- Consider repeating a skin exam in 24 hours.
- Advise the patient to have a follow-up exam in three to five days, including a CBC with differential, with their primary physician.
- Ensure the patient's contact information is correct and current.

Internal Contamination Therapy Recommendations in the U.S. for Radionuclides of Concern

Refer to the tables about managing internal radiation contamination at **remm.hhs.gov/int_contamination.htm** on the REMM website.

CDC Specimen Collection for Bioassay of Internal Contamination

Collect 40 to 60mL of urine for each person in a urine cup with a screw cap. Use the following steps (which were adapted from the CDC)[20]:

1. Wash hands with soap and water.
2. Collect 40 to 60 mL of urine in a urine cup with a screw cap.
3. Screw the cap on tightly and apply the appropriate identifiers (for example, the medical records number, specimen identification number, collector's initials, date and time of collection, and barcode technology).
4. Indicate the method of collection if other than "clean catch" (obtained by catheterization).
5. Freeze samples as soon as possible (at minus 70 degrees Celsius or by using dry ice is preferred).
6. Prepare samples for shipment. Acquire a polystyrene foam-insulated corrugated fiberboard shipper for biological substance Category B samples.
7. For each lot number of urine cups used for collection, provide two empty, unopened urine cups to be used as blanks for measuring background contamination.
8. Ship the bioassay samples to the CDC's laboratory. Use appropriate and regulatory-approved shipping containers and procedures for biological specimens. Consult with the shipping specialists in your facility.
9. Maintain a list of names with corresponding specimen identification numbers at the collection site so results can be reported to patients and their health care providers. It is recommended that you record if counter measures were administered prior to sample collection and indicate if the sample was collected postmortem.
10. Recognize that analysis by the CDC will not be rapid. Diagnoses and treatment of ARS or decisions related to decorporation of radioisotopes known to have been internalized should move forward without these results.

For more detailed shipping instructions, visit **emergency.cdc.gov/radiation/pdf/ShippingInstructions.pdf**.

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[20]Centers for Disease Control and Prevention. Radiological agents: CDC specimen collection protocol for a radiological incident. Published September 2015. Accessed June 10, 2024. **https://emergency.cdc.gov/radiation/pdf/urinecollectionflowchart.pdf**

Sample Patient Discharge Letter Template

Radiation Contamination: Sample Emergency Department Discharge Letter Template

Date: _____ Time: _____
Emergency department (ED) name: _____
Phone number: _____
Patient name: _____ Patient date of birth: _____
Date and time of radiation incident: _____

Dear Health Care Provider,

_____ was evaluated for radiation contamination on _____ at _____ and later discharged on _____ at _____. A summary of the initial assessment and recommended follow-up plan is outlined in this letter along with relevant results. **As of the writing of this letter, the patient has not shown any signs or symptoms of acute radiation syndrome (ARS).**

Assessment

Upon admittance to the ED the patient was found to have:

- ☐ External radioactive contamination that was fully removed
- ☐ External radioactive contamination that was partially removed and will not require further treatment or pose other safety concerns at home or at work
- ☐ Potential internal contamination that does not require further management
- ☐ Wounds that have been treated and irrigated for contamination

Plan

- ☐ The patient shall return to the ED if they experience symptoms of ARS or cutaneous radiation injury (CRI) **less than 48 hours** from the time of the incident.
- ☐ The patient must collect a urine sample for 24 hours after being discharged from the ED, according to the instructions provided.
- ☐ The patient shall see their primary care provider within 24 hours for:
  - ☐ An immediate complete blood count with differential (if there are concerns about radiation exposure) — for interpretation, visit remm.hhs.gov/ars.htm
  - ☐ Wound assessment (see the attached wound care instructions)
- ☐ The patient should see their primary care provider within three to five days for:
  - ☐ Wound assessment (see the attached wound care instructions)
  - ☐ General follow-up
- ☐ The patient should see their primary care provider or return to the ED if they experience symptoms of ARS or CRI **more than 48 hours** after the time of the incident.

Best regards,

_____
_____

For more information, visit cdc.gov and search for radiation emergencies.

To download a copy of the sample discharge letter template, visit **on.nyc.gov/discharge-letter-template.**

Glossary

Absorbed dose: The amount of energy deposited by ionizing radiation in a unit mass of tissue. Units: joule per kilogram (J/kg), designated Gy.

Activity (radioactivity): The rate of decay of radioactive atoms disintegrating per second. Units: becquerels (Bq) or curies (Ci) (1 Ci = 3.7 E+10 dps).

Acute exposure: A very rapid exposure to radiation that occurs in seconds or minutes.

Acute radiation syndrome (ARS): A serious illness resulting from an acute exposure dose of at least 75 rem of penetrating radiation to a large part of the body. The severity of symptoms is proportional to the dose, culminating in death with doses approaching 1,000 rad (10 Gy). Usually described as constellations of effects arising from the tissues being damaged known as subsyndromes: hematopoietic (onset at lower doses – ≤ 100 rad [1 Gy]), gastrointestinal (onset at 60 rad [6 Gy] and above) and cerebrovascular (onset at high doses – ≥ 1,000 rad [10 Gy] – and is universally fatal). ARS consists of four phases:

- Prodromal stage: Onset and severity inversely related to dose and can occur from minutes to days after exposure. Symptoms include nausea, vomiting, fatigue, diarrhea and loss of consciousness.
- Latent stage: Can last from a few hours to a few weeks. The patient feels generally well.
- Manifest illness: Overt disease with symptoms dependent on the subsyndromes involved. The patient is susceptible to infections, loss of blood, severe fluid shifts with electrolyte imbalances or cardiovascular collapse. This stage can last from hours to several months.
- Recovery or death: Death can be in days, whereas recovery may last for years depending on the exposure dose.

Alpha particle: The nucleus of a helium atom, made up of two neutrons and two protons with a charge of positive 2 emitted by certain radioactive atoms. Alpha particles are characterized by larger deposits of energy per unit length of travel than beta particles and gamma rays. Therefore, they are more damaging when in contact with living tissue via inhalation or ingestion. This same characteristic makes them easy to shield with thin layers of material such as paper. The dead layer of skin is also an effective shield. However, if inhaled or ingested in significant quantities, alpha-emitting radioactivity can deliver a significant radiation dose with severe health impacts.

Background radiation: Ionizing radiation from five natural sources: terrestrial (radionuclides in rocks and soil), cosmic (from sources in outer space), cosmogenic (sources created in the atmosphere by penetrating cosmic rays), internal (radioactivity ingested by humans through food and water) and radon (the major contribution to human dose from naturally produced radon gas and its decay products).

Becquerel (Bq): A measure of radioactive decay — one disintegration per second.

Beta particles: Electrons ejected from the nucleus of a decaying atom. The charge (positive or negative) depends on the radioactive atom. Beta radiation is characterized by its ability to penetrate the dead layer of skin potentially causing "beta burns." They can deliver significant doses if ingested or inhaled.

Contamination (radioactive): External contamination is the deposition of unwanted radioactive material on the surfaces of structures, areas, objects or people. Internal contamination is radioactive material that has been inhaled, ingested or absorbed through the skin.

Cutaneous radiation injury (CRI): A complex syndrome resulting from radiation exposure of more than 200 rad to the skin. Immediate effects can be reddening and swelling of the exposed area (like a severe burn), blisters, ulcers on the skin, hair loss and severe pain. Very large doses can result in permanent hair loss, scarring, altered skin color, deterioration of the affected body part and death of the affected tissue (requiring surgery).

Decay (radioactive): The disintegration (transformation) of the nucleus of an unstable atom to another atom with the release of radiation.

Decontamination: The reduction or removal of radioactive contamination from a structure, object or person.

Deterministic effects: Effects that can be related directly to the radiation dose received. The severity increases as the dose increases. A deterministic effect typically has a threshold below which the effect will not occur. See also stochastic effects.

Dirty bomb: Also known as a "radiation dispersal device" (RDD). A device designed to spread radioactive material by conventional explosives when the bomb explodes. A dirty bomb kills or injures people through the initial blast of the conventional explosive and spreads radioactive contamination over possibly a large area, hence the term "dirty." Examples of such bombs include pressure-cooker or backpack-size bombs incorporating radioactive material, or large truck bombs that include radioactivity. A dirty bomb is not a nuclear weapon and is much simpler to make.

Dose (radiation): A numerical value of radiation energy absorbed by a person's body. Several different units are used to describe radiation dose.

Dose rate: A numerical value of the radiation dose delivered per unit of time.

Dosimeter: A small portable instrument (such as a thermoluminescent dosimeter, an optically stimulated dosimeter or an electronic pocket dosimeter) for measuring and recording the total accumulated dose of ionizing radiation a person receives in a period of time.

Dosimetry: An assessment (by measurement or calculation) of radiation dose.

Exposure (radiation): A measure of ionization in the air caused by X-rays or gamma rays only. The unit of exposure most often used is the roentgen.

External exposure: Exposure to radiation outside of the body.

Gamma rays: High-energy electromagnetic radiation emitted by certain radionuclides when their nuclei transition from a higher to a lower energy state (often referred to as "penetrating" or "photon" radiation). They are characterized by:

- A relatively high-energy and short wavelength
- A unique energy for a given radioactive element, a characteristic that enables scientists to identify which gamma emitters are present in a sample
- The penetration into tissue farther than beta or alpha particles
- A lower deposited energy per unit length of track than alpha and beta radiation
- Similar to X-rays except they originate in the nucleus of a decaying atom

Gray (Gy): A unit of measurement for absorbed dose. It measures the amount of energy absorbed in a material. The unit Gy can be used for any type of radiation but does not describe or account for the biological effects of the different radiations.

Internal exposure: An exposure to radioactive material taken into the body.

Isotope: A nuclide of an element having the same number of protons but a different number of neutrons. An isotope of hydrogen (one proton) is hydrogen-3 (or "tritium"), which has one proton and two neutrons.

Latent period: The time between exposure to a toxic material and the appearance of a resultant health effect.

Nuclide: A general term applicable to all atomic forms of an element. Nuclides are characterized by the number of protons and neutrons in the nucleus as well as the energy state of its nucleus. Radioactive atoms are often referred to as radionuclides to emphasize that they are nuclides (isotopes) of an element that is radioactive.

Penetrating radiation: Radiation that can penetrate the skin and reach internal organs and tissues where it can deposit energy (deliver a dose) and cause damage. Photons (gamma rays and X-rays), neutrons and protons are penetrating radiations. In contrast, alpha particles and all but extremely high-energy beta particles are not considered penetrating radiation. Alpha particles can deliver a dose to internal organs, such as the lungs, if inhaled and put in intimate contact with tissue. Beta particles can deliver a skin dose and an internal dose.

Photon: A discrete "packet" of pure electromagnetic energy with no mass, characterized by its ability to penetrate matter. The term "photon" was developed to describe energy when it acts like a particle (causing interactions at the molecular or atomic level) rather than a wave. Gamma rays and X-rays are photons.

Prenatal radiation exposure: Radiation exposure to an embryo or a fetus while it is still in the mother's womb. At certain stages of the pregnancy, the fetus is particularly sensitive to radiation. The probability for severe consequences, especially to brain function, increases when exposure is above 5 rad.

Radiation: Energy moving in the form of particles or waves. Familiar radiations are heat, light, radio waves and microwaves. Ionizing radiation (the radiation considered in this document) is a high-energy (short wavelength, high frequency) form of electromagnetic radiation that can remove electrons from atoms (ionize them), which can result in lasting damage.

Radiation absorbed dose (rad): The traditional unit of absorbed dose equal to 100 erg of radiation energy per gram of material. The unit Gy is equivalent to 100 rad.

Radioactive material: Substances that contain unstable (radioactive) atoms that emit ionizing radiation as they decay. The substances may be incorporated or mixed into stable materials, essentially making the entire material radioactive.

Radioactivity: The process of spontaneous decay (disintegration or transformation) of the nucleus, generally with the emission of alpha or beta particles often accompanied by gamma rays. This process is also referred to as decay or disintegration of an atom.

Radium: A naturally occurring radioactive metal. Radium is a radionuclide formed by the decay of uranium and thorium in the environment. It occurs at low levels in virtually all rock, soil, water, plants and animals. Radon gas is a decay product of radium.

Roentgen (R): A unit of exposure to X-rays or gamma rays. One roentgen is the amount of gamma rays or X-rays needed to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions.

Roentgen equivalent man (rem): A unit of equivalent dose. Not all radiation has the same biological effect for the same amount of absorbed dose. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation by multiplying the number of rads with the quality factor, a number reflecting the potential damage caused by the particular type of radiation. The rem is the traditional unit of equivalent dose. The unit sievert is equal to 100 rem.

Shielding: The material between a radiation source and potentially exposed object or person that reduces the source exposure.

Sievert (Sv): A unit of equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect for the same amount of absorbed dose. Dose equivalent is often expressed as millionths of a sievert (or microsieverts). One sievert is equal to 100 rem.

Stochastic effects: Effects that occur on a random basis independent of the size of dose. The effect typically has no threshold, with the probability of observing the effect increasing with dose. If it occurs, the severity of a stochastic effect is independent of the dose received. Cancer is a stochastic effect.

Terrestrial radiation: Radiation emitted by naturally occurring radioactive materials, such as uranium, thorium and radon in the rocks and soil of the earth.

Whole body exposure: An exposure of the body to radiation in which the entire body, rather than an isolated part, is irradiated by an external source. Whole body exposures are more biologically damaging than partial body exposures.

X-rays: Electromagnetic radiation caused by the deflection of electrons from their original paths or the result of inner orbital electrons that change their orbital levels around the atomic nucleus. X-rays, like gamma rays, can travel long distances through air and most other materials. Like gamma rays, X-rays require more shielding to reduce their intensity than beta or alpha particles. X-rays and gamma rays differ primarily in their origin: X-rays originate in the electronic shell, while gamma rays originate in the nucleus.


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