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

Words written in red or blue have links attached. Clicking on the word or words will pull up the appropriate topic.

Clicking on the radiation icon will return to the page that is open.

The ED is alerted: casualties from the radiological incident on the way

Assume the casualties are radiologically contaminated and their arrival is imminent. What needs to be done right now?

This guidance was created to jump start early actions, how to recruit help with radiological questions from knowledgeable staff available within the facility as well as preparing the ED and staff for contaminated patients. The following will be discussed:

- *Rapidly preparing the ED for arrival of contaminated patients*
- *Working with radioactive casualties*
- *Surgical considerations*
- APPENDICES

Brief Refresher

- As is customary and routine for the ED staff, *treating and stabilizing the injured patient is the priority* above radiological considerations.
- Radiological contamination is in the form of dust, debris or shrapnel containing radioactive compounds.
- Most radiological contamination entering the ED with the patient will be “a nuisance” because it will be in amounts not dangerous to staff caring for the patient.
- Know who in the facility can assist you with radiation questions; the Radiation Safety Officer, Health Physicist or Medical Physicist.

The recommendations in this document apply to the early and intermediate phases after an explosive radiological incident, usually the first 1-2 days, and does not attempt to fully describe prolonged medical management or follow-up of Acute Radiation Syndromes or long term management of internal contamination. Many references and textbooks address those topics (for example CDC, REMM, REAC/TS websites) readers are encouraged to review those for more detailed management protocols.

Preparing the Staff and the Facility

If there is time, this link Working with Radiological Contamination.pdf has a checklist for preparing the ED for radiologically contaminated patients, however it requires time to lay down impermeable layers and taping them down, etc.

For review of radiological modes of exposure see Radiation Exposure vs Contamination.

Consider all patients contaminated until they have been screened using a radiation detector. The lack of visible contamination (dust and debris) on patients does not mean the patient is not contaminated.

- Radiation levels from radioactive contamination will most likely be very low and not dangerous to the staff providing patient care.
- Patient care ***should proceed as usual and not be affected because of contamination*** (do not delay moving the patient to the surgical or radiological suites, or other studies because of concern over the spread of low levels of contamination). Contamination can be cleaned up.

*Important Actions**

Following notification of radiologically contaminated patients transport and their arrival to the ambulance bay, take time to:

QUICK START

E	**E**QUIPMENT-***LOCATE*** radiation survey equipment
D	**D**OSIMETERS- DISTRIBUTE to ED staff
P	**PPE**: Protective Personal Equipment-standard precautions. **Don** standard precautions (see Donning Personal Protective Equipment.pdf); **Double gloves**- outer gloves should be changed frequently. Change gown and gloves if contamination found either visually or by survey. To remove PPE see: Doffing personal Protective Equipment.pdf.
R	**R**ADIATION CONTROL AREAS- designate areas for triage of public and treatment areas. Place signage that area is radioactively contaminated
E	**E**XPERTS IN RADIATION MONITORING- usually RSO (Radiation Safety Officer) are in the hospital, Health or Medical Physicists are likely on staff
P	**P**ADS on floor- absorbent pads with impermeable backing if available or if time cover floor with water impermeable paper or covering, and tape them down.

In addition:

- Recruit staff from other hospital areas, give them PPE and a dosimeter.
- Survey, Survey, Survey- surfaces, sinks, walls, patients, PPE on staff

For a complete list for Facility Prep: see Preparing the Emergency Department Radiologically Contaminated Patients.pdf

Medical Management of Multiple Casualties from a Radiological Incident

- Expect trauma from the explosion,
- Check for highly radioactive embedded shrapnel and remove if present Removing Radioactive Shrapnel.pdf

Casualty characteristics:

Explosive injury patterns:

1. Primary blast injury: highly pressurized blast wave moves through body and organs.
2. Secondary blast injury: blast wave drives bomb debris into victims (shrapnel injuries):
   a. If the bomb debris contains radioactive material then the skin and wounds will be contaminated;
   b. If an embedded fragment is highly radioactive then the victim may sustain significant external exposure;
   c. If victim has prolonged extraction, can incur significant external exposure from groundshine (radioactive emissions from gamma/beta contaminated material on ground and surfaces).
3. Tertiary blast injury: victim propelled through air.
4. Quaternary blast injury: other injuries related to explosion; e.g. burns, exacerbation of chronic disease, crush injuries.

As in any other emergency ***addressing the most immediate life threatening emergencies are paramount***.

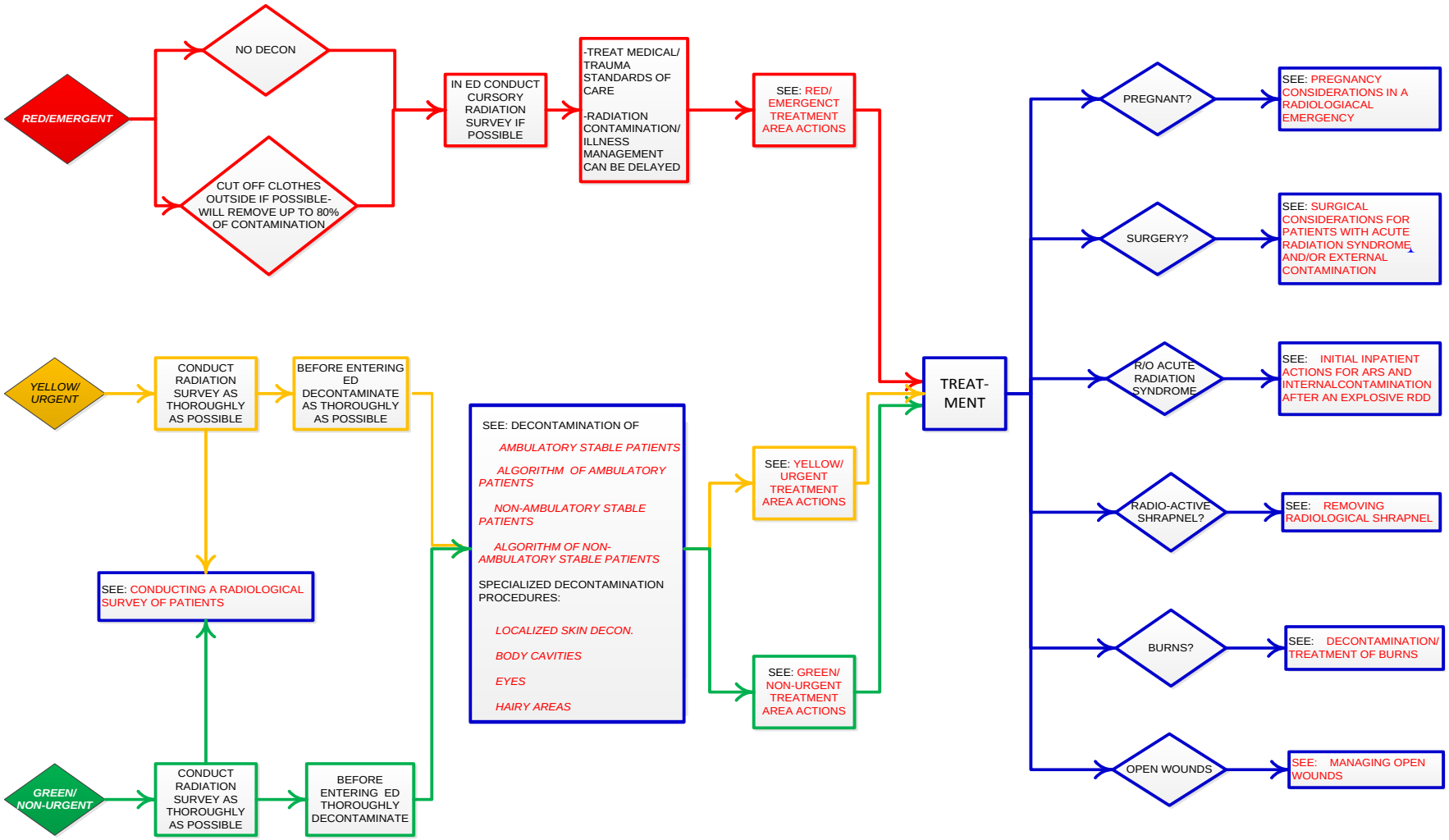
Treatment priorities in order are:

1. ***Ensure the safety of the responders***
2. ***Evaluate and treat patients with life-threatening injuries***
3. ***Manage radiation issues, including internal and external contamination and external exposure***

Critical trauma that is contaminated should be cared for in a room with space and equipment appropriate for the level of care.

Once patient has moved on, room and equipment will need to be cleaned and surveyed with a radiation detector for residual radiation. It is likely the radiation level from a contaminated piece of equipment will be low. The external equipment can be used again if necessary. Replace with decontaminated clean equipment when possible.

Triage by Emergency Category



Surgical Considerations for Patients with Acute Radiation Syndrome and/or External Contamination

If there is a risk of Acute Radiation Syndrome (ARS); total exposure dose unknown:

Suggested treatment sequence for victims of trauma with exposure who are at risk of Acute Radiation Syndrome

1st Treat life or limb threatening injuries

2nd Assess patient for Acute Radiation Syndrome†

†Consider early use of granulocyte stimulating cytokines especially if will be going to surgery

3rd Consider timing of surgery, if possible operate within 48 hours of the event‡

‡ This is especially true if patient is suspected of an exposure of 1 Gray

4th Remove radioactive shrapnel

5th Care for open wounds with possible radioactive contamination

If the patient is radioactively contaminated:

Assuming the patient is uniformly contaminated using 2 levels (10 and 100 Ci/cm^2)- obtain contamination levels from RSO or Heath Physicist) and emitting a constant radiation exposure dose (highly unlikely in a real situation), the following is the time needed for surgical staff standing 20 cm from nearest surface of patient, to reach a dosage of:

1. *5 rem*: Recommended upper limit for healthcare workers in an emergency situation
2. *25 rem*: Recommended upper limit for life saving for first responders; there is very little deterministic risk of health effects; stochastic health effects is a 1% increase in lifetime risk of cancer (~ 28%)

Table calculated assuming a distance of 20 cm between the front surface of the surgeon at mid torso and the nearest surface of the patient with uniform external contamination over entire body[1]

Contamination level on surface of patient		10 µCi per cm2		100 µCi per cm22	
Recommended maximum exposure dose for emergency actions		5 rem	25 rem	5 rem	25 rem
Time near patient for worker to reach recommended maximum exposure dose	Cobalt- 60	13 hrs	64 hrs	77 min	6 hrs
	Iridium- 192	33 hrs	170 hrs	3 hrs	17 hrs
	Cesium- 137	51 hrs	250 hrs	5 hrs	25 hrs
	Americium- 241	760 hrs	3,800 hrs	76 hrs	380 hrs

[1] Health Physics". November 2005, Volume 89, Number 5. Smith, et al.

Pregnancy Considerations in a Radiological Emergency

With pregnant patients, general issues to keep in mind:

- Maternal survival is the most important concern in fetal survival
  - Due to the complicated clinical picture that a gravida patient with traumatic injuries can present, radiography studies should be considered for treatment clarity as the dose to the fetus is an acceptable risk when the maternal outcome will benefit[2]. The use of CT scans that expose the fetus to higher doses when other options are not available or acceptable should be performed when the survival of the pregnancy or mother is in question.
- Fetal doses due to external radiation exposure are generally less than total dose to the mother due to the fact that the uterine wall and maternal abdominal wall provide shielding to the fetus.
- Fetal doses due to internal contamination are also generally less than total dose to the mother with the except in situations involving isotopes affecting the thyroid (fetal thyroid is actively growing and more iodine sensitive than adult thyroid) or isotopes collecting in the maternal bladder (due to proximity to fetus)
  - For internal contamination counter-measures, pregnant patients should receive priority for treatment for the prevention of long term effects (stochastic effects) in the fetus
- Below a *fetal dose of 5 rem*, there is no significant risk of fetal malformation, reduced IQ or other developmental abnormality. Any pregnant woman exposed to this dose or greater (or suspected to have been) should have specific counseling in consultation with a health physicist and maternal-fetal specialist

EXAMINATION[3] RADIOGRAPHY	**ESTIMATED FETAL DOSE (rem)**	**EXAMINATION** COMPUTED TOMOGRAPHY	**ESTIMATED FETAL DOSE (rem)**
Cervical Spine (AP, lateral)	<0.0001	Head	0
Extremities	<0.0001	Chest (routine)	0.002
Chest (PA, lateral)	0.0002	Chest (pulmonary embolism protocol)	0.02
Thoracic spine	0.0003	Abdomen	0.4
Abdominal (AP) (21cm patient thickness)	0.1	Abdomen and pelvis	2.5
Abdominal (AP) (33 cm patient thickness)	0.3	CT angiography of the aorta	3.4
Lumbar Spine (AP, lateral)	0.1	CT angiography of the coronary arteries	0

[2] RSNA Radiographics May-June, 2014. Volume 34, Issue 3. Constantine et al. page 1

[3] From the table -RSNA Radiographics May-June, 2014. Volume 34, Issue 3. Constantine et al.

Any concerns about the exposure dose to the fetus either from the incident or proposed radiography studies and the mother is not in a life threatened situation, one can consult with a qualified and competent medical physicist or health physicist. They can calculate the actual dose to the fetus and can advise on diagnostic studies, treatment plans, etc. especially prior to any decision concerning continuation of the pregnancy.

Gestational age and radiation dose are important determinants of potential non-cancer health effects. The following points are of particular note:[4]

- **Before about 2 weeks gestation (i.e., the time after conception), the health effect of concern from an exposure of > 0.1 gray (Gy) or 10 rads is the death of the embryo. If the embryo survives, however, radiation-induced noncancer health effects are unlikely, no matter what the radiation dose.** Because 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, and the blastocyst will fail to implant in the uterus. Embryos that survive, however, will exhibit few congenital abnormalities.
- **In all stages of gestation, radiation-induced noncancer health effects are not detectable for fetal doses below about 0.05 Gy (5 rads).** Most researchers agree that a dose of < 0.05 Gy (5 rads) represents no measurable noncancer 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 0.05–0.10 Gy (5–10 rads) range for some stages of gestation. However, a practical threshold for congenital effects in the human embryo or fetus is most likely between 0.10–0.20 Gy (10–20 rads).
- **From about 16 weeks' gestation to birth, radiation-induced noncancer health effects are unlikely below about 0.50 Gy (50 rads).** Although some researchers suggest that a small possibility exists for impaired brain function above 0.10 Gy (10 rads) in the 16- to 25-week stage of gestation, most researchers agree that after about 16 weeks' gestation, the threshold for congenital effects in the human embryo or fetus is approximately 0.50–0.70 Gy (50–70 rads).

[4] CDC. Radiation and Pregnancy: A Fact Sheet for Clinicians. https://emergency.cdc.gov/radiation/prenatalphysician.asp

Prioritizing Patients for the Management of Radiological Injuries

1st Priority

TRIAGE

Medical and Traumatic Injuries

2nd Priority

ASSESS

For Potential Radiological Exposure/ Contamination

3rd Priority

OBSERVE

In ED for Possible Acute Radiation Syndrome

4th Priority

TREAT

If Radiological Countermeasures are Appropriate

Is it safe to work closely with contaminated patients?

The answer is yes, if you take appropriate precautions.

➢Radiation contamination is considered a nuisance problem by radiation workers.

➢Historically, providers who cared for the heavily contaminated firemen and responders to the nuclear power plant catastrophe at Chernobyl in 1987 wore no PPE and victims were not immediately decontaminated. The maximum dose *to* the providers working closely with these patients was calculated to be approximately 10 mrem, or the amount of a chest XRAY.

➢The caveat to this is if there is a possibility for “hot fragments” to be embedded in patient’s clothing or body or for the external contamination to be so dense as to create a possible risk to the ED physician or surgeon working in close proximity to a critically injured patient.

*1st **Priority**: Triage of Medical and Traumatic Injuries*

The following medical triage categories indicate how and when to address decontamination in this process.

RED (MEDICAL EMERGENCY TAG)

- Patients requiring ***immediate attention*** due to incident caused injury or illness may be heavily contaminated and possibly have *sustained significant exposure*
- If possible, decontamination starts outside the ED with removal of the patient's clothing [this can achieve up to 70-90% decontamination], transfer to a clean stretcher, and cover with a clean sheet prior moving into the Medical/Trauma Emergency Treatment Area.
- Conduct cursory radiation survey during stabilization of patient

YELLOW: (MEDICAL URGENCY TAG)

- Patients with ***urgent medical or traumatic injuries***
- Patients should have a thorough radiological body survey before entering ED
- Decontaminate as completely as feasible before entering ED treatment areas

GREEN: (NON- URGENT with or without MINOR ILLNESS OR INJURY)

- Patients should have a thorough radiological body survey before entering ED
- If possible, a thorough decontamination should proceed before patient enters treatment area
- If patient numbers are large then consider limiting decontamination to only hands and face and change of external clothing. Before discharge, the patient should be directed to decontaminate once they are home.

Brief Note

NYC added an intermediate category, the ORANGE category that takes into account the changes that may occur in a victim's status due to the progressive worsening of the injury or exacerbation of chronic disease. Orange tags are NYC specific.

2nd ***Priority:*** *Triage for Potential Radiological Exposure and/or Contamination*

I. *Highest Risk Patients: Serious injuries related to the incident*

Patients with major injuries were close to the explosion, triaged **RED/EMERGENT** are more likely to have:

- Prolonged extrication from the highest levels of radiation exposure and ground contamination;
- Contaminated wounds (radioactive shrapnel may be present);

Children < 18 years old and fetuses of pregnant women rank higher due to their susceptibility to radiation (this is true for all exposure).

These patients will likely be admitted, which allows clinicians ample time for patient observation and collection of 24 hour urine samples and performance of serial Complete Blood Counts (CBC) tests.

II. *Patients with moderate and mild injury/illness related to the incident.*

Those patients with moderate or mild injuries **YELLOW/ URGENT** (possibly a few GREEN/MINOR) have a greater chance of internal contamination due to their proximity to the epicenter:

- Open wounds, are considered as a higher risk of radiation injury or internal contamination;
- Most will not require hospital admission, but may require some assessment for radiation contamination and exposure prior to discharge from the ED.

III. *Patients that are non-injured and asymptomatic but with facial and/or upper body contamination*

- Facial and upper body contamination is an indicator that a patient is at increased risk for internal contamination. These persons should be ranked behind persons falling into the first two categories to receive bioassays or radiation countermeasures.

IV. *Children less than 18years old of age and pregnant women in contaminated areas, without evidence of external contamination*

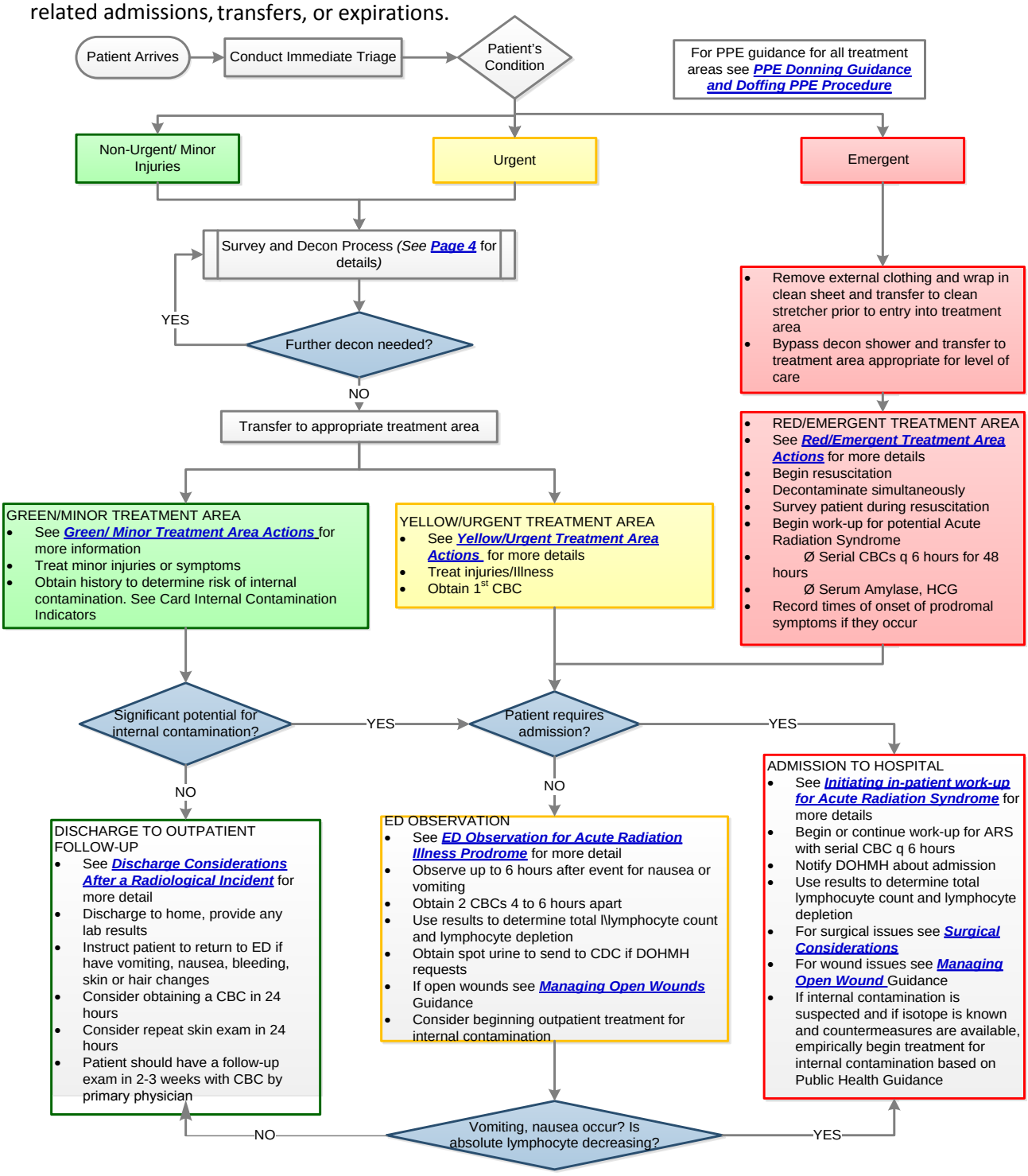
- Within the non-injured and asymptomatic patients in the **GREEN/MINOR** triaged patients, children less than 75 pounds and pregnant women with close proximity to the explosive event and no other evidence of injury or contamination would be the fourth in line for bioassays.

V. *All other individuals without physical injuries or evidence of contamination.*

- Direct to alternative care area to obtain demographics, counseling and assessment, or discharge home to follow up with primary MD or other medical providers or agencies. Obtain demographics on all persons presenting from incident if possible.

3rd Priority: *Who needs ED Observation for Possible Acute Radiation Syndrome?*

Pregnant women and children under 18 should have priority for resources. See ***Pregnancy Considerations in a Radiological Emergency*** guidance for more details. Notify DOHMH for incident related admissions, transfers, or expirations.



4th Priority: Considerations for Administration of Countermeasures for Acute Radiation Syndrome or Internal Contamination

It is unlikely that the patient will be overtly symptomatic due to internal contamination, therefore use the following signs and facts from the patient's history as a proxy to determine if countermeasures are warranted:

- External contamination around the face and neck
- Open wounds with contamination or foreign bodies
- Moderately to seriously injured
- Prolonged time spent in contaminated area without respiratory protection
- Prolonged extraction time.

Definitive testing for internal contamination is a bioassay of urine or feces but this is a sparse resource. Other quantitative measures are available and will be utilized as best as possible but the initial treatment decisions will be based on the proxies above. Historically, most treatment decisions for internal contamination have been made empirically (presumptive) without quantitative body burden results.

Contact DOHMH for incident specific case definitions and if countermeasures are available for radionuclides present from incident. DOHMH will provide guidelines for treatment, bioassay collection, and recommended follow-up.

Countermeasures DOHMH will obtain for treatment

- ***Filgrastim (Neupogen) and Pegfilgrastim (Neulasta)*** for the Hematopoietic Syndrome of ARS: Granulocyte colony stimulating factors (filgrastim and pegfilgrastim) stimulates the production of white blood cells to decrease neutropenic nadir and duration

- ***Potassium iodide*** for Iodine- 131: KI saturates the thyroid blocking receptors so very little radioactive iodine binds to the organ.

- ***Prussian blue*** for Cesium-137: Prussian blue binds with radioactive cesium in the gut and blocks reabsorption decreasing body burden and reducing biological half-life from 110 days to 30 days.

- ***DTPA**** for Plutonium -238, 239, 240 and Americium -249: DTPA binds plutonium, americium and curium in the blood enhancing excretion through the kidneys reducing body burden

Guidance for administration of countermeasures is available at Radiation Emergency Medical Management website https://www.remm.nlm.gov/Countermeasures.pdf.

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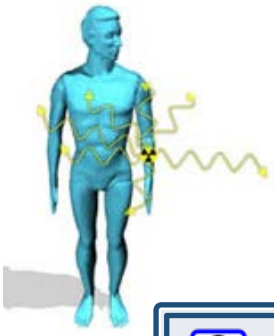
*DTPA: Diethylenetriaminepentaacetic acid

Radiation Exposure vs. Contamination for Your Safety

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.
- 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.
- Irradiated patients do not emit radiation and radiation survey meters *will not register* when individuals have only had external exposure (just as a patient who had a CXR is not radioactive)

EXTERNAL CONTAMINATION (Radioactive material on the outside of the body)



- Radioactive material (liquid, powder, metal fragments, dust) contamination on the body surface or clothing.
- External contamination may be removed by washing with water or simply taking off the outer layers of clothing.
- Once external contamination is removed and away from the body, it no longer has an effect on the body or emits radiation.
- Wearing Standard Precautions will prevent the spread of external contamination to you.

An individual with radioactive gamma emitters. For example cesium, cobalt on them can be radioactive (the contamination can emit radiation). Until the radioactive material is removed a caregiver can be exposed. Decontaminate those from the incident site before treatment unless someone's *injuries are life threatening*.

INTERNAL CONTAMINATION

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

DOSE RECONSTRUCTION: The process of estimating total radiation doses that were received by individuals or populations. The total dose is the sum of doses from exposure in the environment (irradiation) plus from internal and external contamination. Dose reconstruction is typically conducted be subject matter experts, such as health physicists because of its complexity.

A

Absorbed dose: the amount of energy deposited by ionizing radiation in a unit mass of tissue. It is expressed in units of joule per kilogram (J/kg), and called “gray” (Gy).

Activity (radioactivity): the rate of decay of radioactive material expressed as the number of atoms breaking down per second measured in units called becquerels or curies.

Acute exposure: an exposure to radiation that occurred in a matter of minutes rather than in longer, continuing exposure over a period of time.

Acute Radiation Syndrome (ARS):

- Received a dose greater than 75 rads of penetrating radiation to the body in a short time (usually minutes). If the exposure has been approximately 1,000 rads or more, death may occur within 2 – 4 weeks.
- Earliest symptoms are
    - nausea,
    - fatigue,
    - vomiting,
    - diarrhea.
- Hair loss, bleeding, swelling of the mouth and throat, and general loss of energy may follow.

Alpha particle: the nucleus of a helium atom, made up of two neutrons and two protons with a charge of +2.

- Certain radioactive nuclei emit alpha particles.
- Generally carry more energy than gamma or beta particles, and deposit that energy very quickly while passing through tissue.
- Stopped by a thin layer of light material, such as a sheet of paper, and cannot penetrate the outer, dead layer of skin. Therefore, they do not damage living tissue when outside the body.
- When inhaled or swallowed, however, they are especially damaging because they transfer relatively large amounts of ionizing energy to living cells.

B

Background radiation: ionizing radiation from natural sources, such as terrestrial radiation due to radionuclides in the soil or cosmic radiation originating in outer space.

Becquerel (Bq): the amount of a radioactive material that will undergo one decay (disintegration) per second.

Beta particles: electrons ejected from the nucleus of a decaying atom.

- Can be stopped by a thin sheet of aluminum,
- They can penetrate the dead skin layer, potentially causing burns
- Pose a serious direct or external radiation threat and can be lethal depending on the amount received.
- Pose a serious internal radiation threat if beta-emitting atoms are ingested or inhaled.

Biological half-life: the time required for one half of the amount of a substance, such as a radionuclide, to be expelled from the body by natural metabolic processes, not counting radioactive decay, once it has been taken in through inhalation, ingestion, or absorption.

C

Contamination (radioactive): the deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or people where it may be external or internal.

Curie (Ci): the traditional measure of radioactivity based on the observed decay rate of 1 gram of radium. One curie of radioactive material will have 37 billion disintegrations in 1 second.

Cutaneous Radiation Syndrome (CRS): the complex syndrome resulting from radiation exposure of more than 200 rads 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).

D

Decay, radioactive: disintegration of the nucleus of an unstable atom by 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.

Dirty bomb: (aka radiation dispersal device) 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." Such bombs could be miniature devices or large truck bombs. A dirty bomb is much simpler to make than a true nuclear weapon.

Dose (radiation): radiation absorbed by person's body. Several different terms describe radiation dose.

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

Dosimeter: a small portable instrument (such as a film badge, thermoluminescent dosimeter [TLD], or pocket dosimeter) for measuring and recording the total accumulated dose of ionizing radiation a person receives.

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

E

Exposure (radiation): a measure of ionization in air caused by x-rays or gamma rays only. The unit of exposure most often used is the roentgen. *See also* contamination.

External exposure: exposure to radiation outside of the body.

G

Gamma rays: high-energy electromagnetic radiation emitted by certain radionuclides when their nuclei transition from a higher to a lower energy state.

- Have high energy and a short wave length.
- All gamma rays emitted from a given isotope have the same energy, a characteristic that enables scientists to identify which gamma emitters are present in a sample.

- Gamma rays penetrate tissue farther than do beta or alpha particles, but leave a lower concentration of ions in their path to potentially cause cell damage.
- Gamma rays are very similar to x-rays.

Genetic effects: hereditary effects (mutations) that can be passed on through reproduction because of changes in sperm or ova.

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 it does not describe the biological effects of the different radiations.

H

Half-life: the time any substance takes to decay by half of its original amount.

I

Internal exposure: 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.

L

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

Local radiation injury (LRI): acute radiation exposure (more than 1,000 rads) to a small, localized part of the body. Most local radiation injuries do not cause death. However, if the exposure is from penetrating radiation (neutrons, x-rays, or gamma rays), internal organs may be damaged and some symptoms of acute radiation syndrome (ARS), including death, may occur. Local radiation injury invariably involves skin damage, and a skin graft or other surgery may be required.

N

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 by the amount of energy contained within the atom.

P

Penetrating radiation: radiation that can penetrate the skin and reach internal organs and tissues. Photons (gamma rays and x-rays), neutrons, and protons are penetrating radiations. However, alpha particles and all but extremely high-energy beta particles are not considered penetrating radiation.

Photon: discrete "packet" of pure electromagnetic energy. Photons have no mass and travel at the speed of light. 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 fetus while it is still in its mother's womb. At certain stages of the pregnancy, the fetus is particularly sensitive to radiation and the health consequences could be severe above 5 rads, especially to brain function.

R

Rad (radiation absorbed dose): a basic unit of absorbed radiation dose. It is a measure of the amount of energy absorbed by the body. The rad is the traditional unit of absorbed dose. It is being replaced by the unit gray (Gy), which is equivalent to 100 rad. One rad equals the dose delivered to an object of 100 ergs of energy per gram of material.

Radiation: energy moving in the form of particles or waves. Familiar radiations are heat, light, radio waves, and microwaves. Ionizing radiation is a very high-energy form of electromagnetic radiation.

Radioactive contamination: the deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or people. It can be airborne, external, or internal.

Radioactive decay: the spontaneous disintegration of the nucleus of an atom.

Radioactive half-life: the time required for a quantity of a radioisotope to decay by half. For example, because the half-life of iodine-131 (I-131) is 8 days, a sample of I-131 that has 10 mCi of activity on January 1, will have 5 mCi of activity 8 days later, on January 9.

Radioactive material: material that contains unstable (radioactive) atoms that give off radiation as they decay.

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

Radioisotope (radioactive isotope): isotopes of an element that have an unstable nucleus. Radioactive isotopes are commonly used in science, industry, and medicine. The nucleus eventually reaches a stable number of protons and neutrons through one or more radioactive decays. Approximately 3,700 natural and artificial radioisotopes have been identified.

Radiological dispersal device (RDD): (aka dirty bomb) a device that disperses radioactive material by conventional explosive or other mechanical means, such as a spray.

Radionuclide: an unstable and therefore radioactive form of a nuclide.

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

Rem (roentgen equivalent, man): a unit of equivalent dose. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. It is determined by multiplying the number of rads by 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, but it is being replaced by the sievert (Sv), which is equal to 100 rem.

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

S

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

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

Somatic effects: effects of radiation that are limited to the exposed person, as distinguished from genetic effects, which may also affect subsequent generations.

Stochastic effect: effect that occurs on a random basis independent of the size of dose. The effect typically has no threshold and is based on probabilities, with the chances of seeing 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.

T

Teratogenic effect: birth defects that are not passed on to future generations, caused by exposure to a toxin as a fetus.

Terrestrial radiation: radiation emitted by naturally occurring radioactive materials, such as uranium (U), thorium (Th), and radon (Rn) in the earth.

W

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.

X

X-ray: electromagnetic radiation caused by deflection of electrons from their original paths, or 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 do beta or alpha particles. X-rays and gamma rays differ primarily in their origin: x-rays originate in the electronic shell; gamma rays originate in the nucleus.

WORKING SAFELY WITH RADIOLOGICAL CONTAMINATION

WORKING WITH CONTAMINATED PATIENTS

Don Personal Protective Equipment (PPE) including a dosimeter (see Guideline 2)

- Wear dosimeter on you where it can easily be read.
- Change outer gloves frequently and always after touching patient or working near patient.

Maintain distance from any radioactive source (even patients if they are radioactively contaminated). While caring for patient, working an arm's length away will decrease your dose.

- *NEVER HANDLE RADIOACTIVE MATERIALS WITH BARE HANDS.* If necessary to remove radioactive contamination, use extended forceps and place material in a lead lined container.
- Follow instructions given to you by a Radiation Safety Officer (RSO), Health or Medical Physicists.

WORKING SAFELY IN A RADIOLOGICALLY CONTAMINATED SPACE

In the event the ED becomes contaminated, the levels will most likely be low and do not present a significant health hazard to staff working in the space.

Health care workers dose limit is 5 rem. This is a regulatory limit and is well within an exposure dose that does not have a significant health impact. It is very likely a healthcare worker will have much lower exposure doses.

- In the unlikely event that high levels of radiation are encountered, non-healthcare workers and visitors will have stricter total exposure dose limits than healthcare personnel and may have to vacate areas that healthcare workers can continue working in.
- Nevertheless, take actions to limit exposure dose to rescue workers and ED staff (see Task List 1).

Designate areas where contaminated patients will be treated or held as *Radiation Control Areas* and inform staff the location of these areas or place signage showing radiation control area.

- In radiation control areas (or if there are other areas with elevated readings) have the hospital Radiation Safety Officer advise on hospital staff stay time limits as per his or her discretion. Inform staff of time limits emphasizing that there is no need to avoid these areas but they can choose to limit their time.
- If possible place contaminated patients in as few areas of ED, marking radiation control areas will facilitate this. Treatment areas for contaminated patients will become contaminated so if possible choose areas that will not have a large impact on the functioning of the ED while area is down waiting for cleaning.
- Minimize unnecessary time in radiation control areas.
- *DO NOT EAT OR DRINK IN RADIATION CONTROL AREAS* – to take a break, staff should go to buffer areas, disrobe, wash hands, and get surveyed prior to eating. This is to prevent the accidental contamination of food or ingestion of radioactive material.
- Have hospital personnel who are knowledgeable about radiation (often this is the Radiation Safety officer) do frequent surveys of contaminated spaces, surfaces (floors, counters, sinks), patients and workers PPE (gowns, gloves).

Designate an area to store radioactive waste that is away from where people are working or waiting. Contaminated materials must be discarded as radiation waste and not biological waste ask the RSO.

- If the area is not necessary, keep staff out until area is cleaned.

PERSONAL PROTECTIVE EQUIPMENT (PPE) DONNING GUIDANCE

Donning Personal Protective Equipment
Personnel working in radiation controlled areas should don the following:
1. Scrub suit and gown (cloth or paper) or Tyvek® overalls;
2. For contaminated patients: respiratory protection- full-face piece air purifying respirator with a P-100 or High Efficiency Particulate Air (HEPA) filter.
3. For post decon patients: respiratory protection is a fit tested N-95 with a face shield and head/hair covering.
4. Double gloves with inside gloves under arm cuff and secured to gown with heavy tape (duct tape or chemical decontamination suit tape); outer gloves should be easily removable.
5. Head cover or bonnet;
6. Waterproof shoe covers
7. Waterproof aprons or outer gowns for staff using liquids for decontamination or at risk for splash of liquids.
Tape shut all open seams and cuffs using water-resistant heavy tape, such as duct tape or chemical decontamination suit tape.
Assign personal self-reading dosimeters to staff working closest with contaminated patients. Attach to outer garment where they can be easily removed and read.
Dosimeters should be placed near the neck under the gown to avoid gross contamination. Staff with direct patient care should wear a dosimeter.

OSHA/NIOSH PPE recommendations for pre-decontamination care of a patient

Standard Precautions without head covering that is recommended (picture of head covering added)

DOFFING PERSONAL PROTECTIVE EQUIPMENT PROCEDURE

Prior to exiting from a controlled area, personnel begin doffing at the control line, the border between controlled area and clean area, as described below:
1. Remove outer gloves first, turning them inside-out as they are pulled off.
2. Provide dosimeter to radiation safety officer or other assigned person (or insure that reading is recorded)
3. Remove all tape at trouser cuffs and sleeves.
4. Remove outer surgical gown, turning it inside-out -- avoid shaking.
5. Remove head cover and mask.
6. Remove shoe cover from one foot and let radiation safety officer or designee monitor shoe; if shoe is clean, step over control line, then remove other shoe cover and monitor other shoe.
7. Remove and discard inner gloves.
8. Conduct total-body radiological survey of each team member.


Step 1


Step 2


Step 3


Step 4


Step 5


Step 6


Step 7

PREPARING THE EMERGENCY DEPARTMENT FOR RADIOLOGICALLY CONTAMINATED PATIENTS

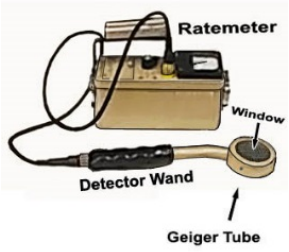
TASK	ASSIGNED TO	DONE
Notify Radiation Safety and other Radiation response trained personnel.		
If an explosive event, institute hospital's mass casualty plan.		
Set up decontamination area as per hospital decontamination plan.		
Make sure area radiation monitors are working and turned on.		
Distribute personal radiation dosimeters as per policy.		
Locate survey meters, check batteries and calibration dates.		
Assign survey meters to people responsible for radiation monitoring as per hospital plan.		
Determine background level outside of ED and within areas where potentially contaminated patients may be treated.		
Set out multiple large, plastic-lined waste containers.		
Cordon off and restrict access to area.		
Place signage to label areas that are clean or potential radiation areas.		
Cover treatment tables in Emergent/Red areas with 1-2 waterproof covers.		
If time permits, cover surfaces and large equipment such as portable X-ray machines in Emergent/Red treatment area with large sheets of plastic.		
Cover floor of entry to ED and treatment areas with butcher paper if time allows.		
Have available change of clothing for patients post decontamination.		
Have sufficient plastic bags for potentially contaminated clothing, dressings, etc.		
Set up Donning and Doffing area and supply with PPE.		
Move pregnant hospital workers to areas that will not manage potentially contaminated patients.		
Set up decontamination area as per hospital decontamination plan.		

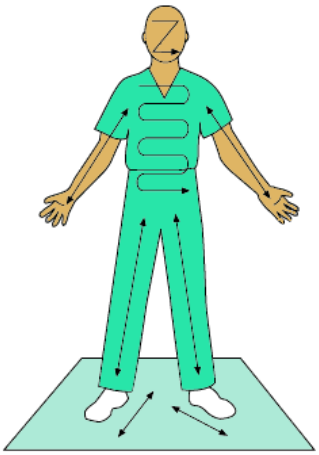
REMOVING RADIOACTIVE SHRAPNEL

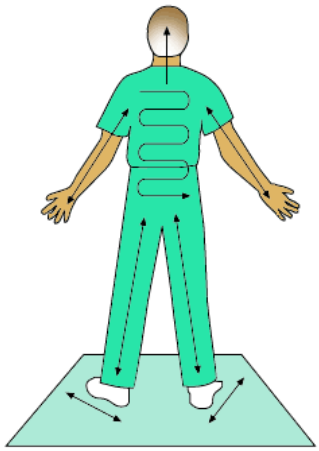
- Consider all open wound/s contaminated until proven otherwise.
- Use appropriate radiation survey meter to evaluate and monitor the medical management of radioactive shrapnel in order to protect medical team.
- Assume embedded foreign bodies will produce uptake (internal contamination).
- Cover skin surrounding open wound/s (with or without foreign bodies) with waterproof dressings or drapes, to limit the spread of radioactivity by water run-off during wound irrigation and decontamination.
- Irrigate wound/s gently with copious amounts of water or saline.
  - Multiple irrigation attempts are usually necessary.
  - Remove visible radioactive foreign bodies (e.g., metallic fragments or shrapnel) using forceps or water-pik.
  - While removing radioactive shrapnel, use long surgical instruments that maximize distance between the operator and the shrapnel.
- Removed foreign bodies and any instruments used to handle foreign bodies should be properly stored in lead containers and labeled by RSO for forensic evaluation and proper disposal.
- 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 wound/s.
  a) Obtain expert medical and health physics advice before excision of vital tissue.
  b) Surgically removed tissue and all surgical supplies should be properly stored and labeled by RSO for forensic evaluation and proper disposal.
- Cover decontaminated wound/s with a waterproof dressing to prevent further contamination.
- Decontaminate skin around wound/s as thoroughly as possible before suturing or other treatment.
- Decontaminate intact skin as described in *Localized Skin Decontamination.*

CONDUCTING A RADIOLOGICAL SURVEY OF PATIENTS

Assume patient is contaminated
Using radiation detection equipment ➢ Surveyor should be trained in using radiological detection equipment ➢ Initially survey face, hands and feet ➢ If results are positive then continue to scan body
Body survey ➢ Survey thoroughly (scan should take 5 to 8 minutes per person) ➢ Move slowly no more than 2 inches per second ➢ Keep approximately 1 inch distance between probe and the surface of the body
Providers should understand what the contamination levels mean as far as risk to the patient and to themselves



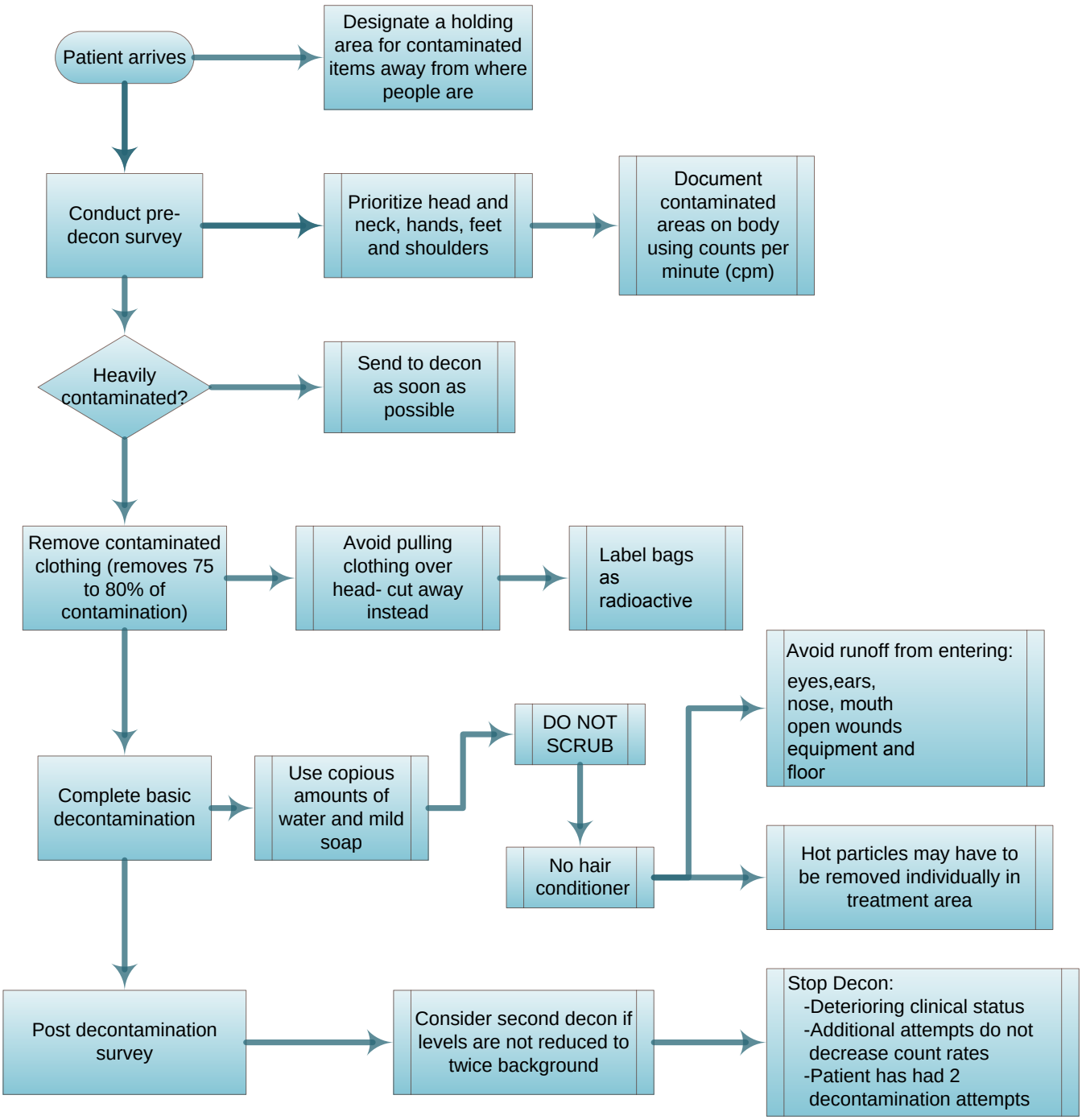




DECONTAMINATION of AMBULATORY STABLE PATIENTS- TABLE of ACTIONS

SEE ALGORITHM (G8)
Pre-Decontamination Survey ➢ Prioritize surveillance of the Head, Neck, Hands, Feet and Shoulders ➢ Mark contaminated areas on body in counts per minute ➢ Send to decontamination if survey becomes to problematic due to: ED surge of victims or lack of available equipment o This is important if the patient is obviously covered in high-risk debris from the explosive site
Remove Contaminated clothing (*removes 75-90% of contamination*) ➢ Designate a holding area for contaminated clothing away from care area ➢ Remove clothing carefully avoiding the face as much as possible o Avoid pulling clothing over the head, such as T-shirts and sweaters, cut away instead ➢ Graphic or pictorial instructions should be available to demonstrate the proper means of removing contaminated clothing ➢ Label bags as radioactive and follow patient identification procedures
Complete Basic Decontamination Wash ➢ Use: o Copious amounts of tepid water o Gentle soap ➢ Do not scrub as may cause small breaks in skin (increases chance of internal uptake) ➢ No hair conditioner (decreases removal of material from hair) ➢ Avoid water runoff from entering the eyes, nose, mouth, or open wounds ➢ Hot particles may need to be removed individually in treatment areas
Post Decontamination Survey: ➢ If feasible, conduct post-decontamination survey ➢ If still greater >1000 cpm, repeat whole body decontamination with a goal of reducing contamination ➢ Stop decontamination if: o The patients clinical status precludes additional decontamination showers o Additional attempts fail to reduce count rates o The patients has undergone 2 whole body decontamination attempts

DECONTAMINATION of STABLE AMBULATORY PATIENTS ALGORITHM

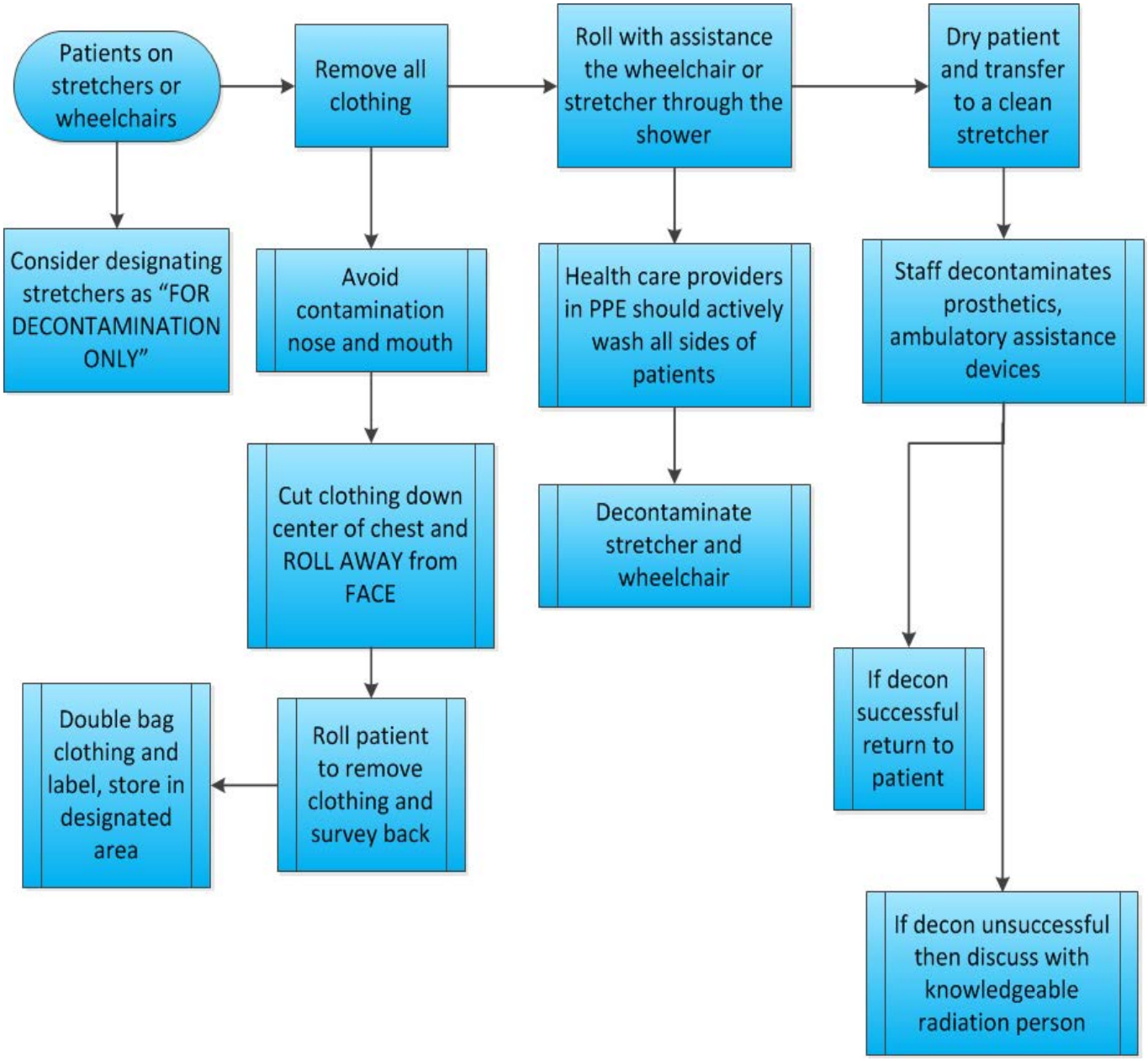


DECONTAMINATION of NON-AMBULATORY PATIENTS WITHOUT LIFE THREATENING CONDITIONS

Patients already on stretchers or wheelchairs (either chronic conditions or acutely from incident) . See G10
All clothing should be removed from patient and equipment ➢ Avoid contaminating the mouth and nose ➢ Cut clothing down center of chest and roll away from face and out from under patient ➢ Secure clothing as radioactive contamination
Consider designating stretchers to be “FOR DECONTAMINATION ONLY”
The patient on the stretcher or wheelchair should then be rolled with assistance through the shower and decontaminated ➢ Health Care providers in PPE should actively wash the patients with particular concern to decontaminate underneath the patient ➢ Decontaminate stretcher or wheelchair simultaneously
Dry patient and transfer to a clean stretcher or wheel chair and cover in clean sheets or gown/scrubs as indicated
Staff decontaminates prosthetics, ambulatory assistance devices and wheelchairs ➢ Return to patient if decontamination attempts are successful ➢ If contamination count remains persistently above 1000 cpm the discuss with Healthy or Medical Physicist
Perform post-decontamination radiological survey

See Decontamination of Non-ambulatory Patients Without Life Threatening Conditions Algorithm G10

DECONTAMINATION of NON-AMBULATORY PATIENTS WITHOUT LIFE THREATENING CONDITIONS ALGORITHM



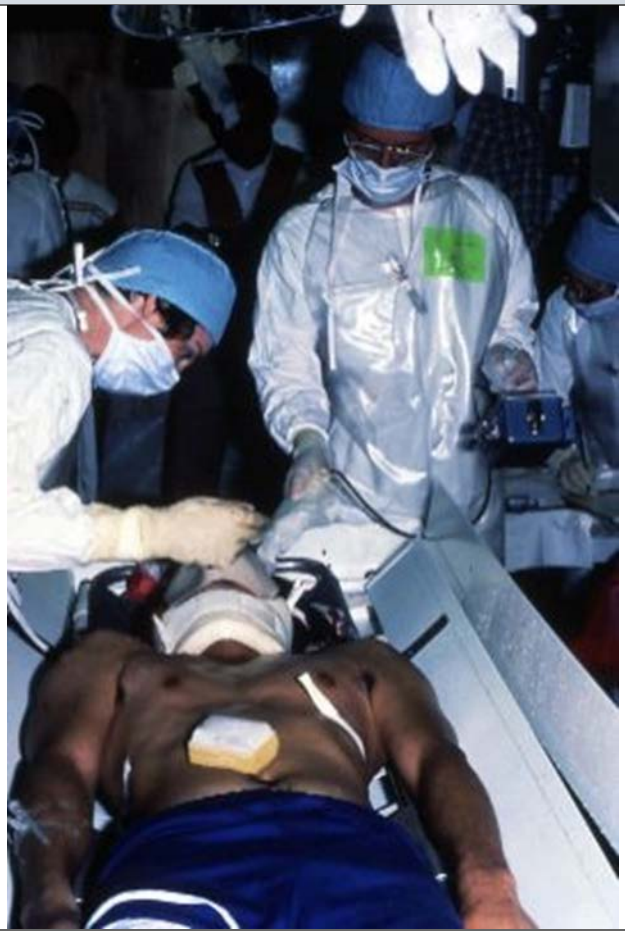
RED/ EMERGENT TREATMENT AREA ACTIONS

OUTSIDE EMERGENCY DEPARTMENT

- Remove external clothing,
- Wrap patient clean sheet, and
- Transfer to clean stretcher prior to entry into ED bypassing decontamination showers

INSIDE RED/EMERGENT TREATMENT AREA

- Continue resuscitation,
- Decontamination simultaneously,
- Survey patient during resuscitation,
- Stabilize patient,
- If patient is admitted begin work up for potential ARS
  - Serial CBCs q 6 hr X 48 hr,
  - Serum Amylase,
  - HCG
- Use results of CBCs to determine total lymphocyte count and lymphocyte depletion
  - Begin 24 hour urine collection for possible bioassay if requested by DOHMH
  - Note times and onset of prodromal symptoms if they occur
- Notify DOHMH about patient and request countermeasures if available.
- If internal contamination is suspected and if isotope is known, and countermeasure available, empirically begin Rx for internal contamination based on Public Health Guidance



RSO surveys patient as staff continues care

YELLOW/URGENT TREATMENT AREA ACTIONS

OUTSIDE EMERGENCY DEPARTMENT
➢ Patient should go through hospital decontamination process prior to entry into Urgent Treatment Area.
INSIDE YELLOW/URGENT TREATMENT AREA
➢ Treat injuries/illness,
➢ Obtain 1st CBC,
➢ Determine risk of internal contamination, o Observe up to 6 hours after event for nausea or vomiting o Obtain second CBCs 4-6 hrs after 1st o Use results to determine total lymphocyte count and lymphocyte depletion o Obtain spot urine for bioassay if requested by public health
➢ If patient is admitted begin work up for potential ARS o serial CBCs q 6 hr X 48 hr, o serum amylase, o HCG o Use results of CBCs to determine total lymphocyte count and lymphocyte depletion o Begin 24 hour urine collection for possible bioassay if requested by DOHMH o Note times and onset of prodromal symptoms if they occur
➢ **Notify DOHMH about patient and discuss countermeasures if available.**
➢ If internal contamination is suspected and if isotope is known, and countermeasure available, empirically begin Rx for internal contamination based on Public Health Guidance.

Manage wounds always as contaminated until proven otherwise

GREEN/MINOR OR NON-INJURED TREATMENT AREA ACTIONS

OUTSIDE EMERGENCY DEPARTMENT
➢ Patient should go through hospital decontamination process prior to entry into Minor Treatment Area.
INSIDE GREEN/MINOR TREATMENT AREA
➢ Treat minor injuries/illness,
➢ Determine risk of internal contamination,
➢ If patient has a significant risk for internal contamination: o Keep patient for ED observation for 4-6 hours prior to discharge, o SEE ED OBSERVATION ACTIONS o Notify DOHMH about patient and discuss countermeasures if available
➢ If patent does not have a significant risk for internal contamination: o Discharge to home or safe location, o Provide any lab results,
➢ Have patient return if vomiting, nausea, bleeding, skin or hair changes occur over the next two weeks o Consider obtaining a CBC in 24 hrs o Consider repeat skin exam in 24 hrs
➢ Patient should have follow up exam in 2-3 weeks with CBC by primary physician

REMOVING RADIOACTIVE SHRAPNEL

- Consider all open wound/s contaminated until proven otherwise.
- Use appropriate radiation survey meter to evaluate and monitor the medical management of radioactive shrapnel in order to protect medical team.
- Assume embedded foreign bodies will produce uptake (internal contamination).
- Cover skin surrounding open wound/s (with or without foreign bodies) with waterproof dressings or drapes, to limit the spread of radioactivity by water run-off during wound irrigation and decontamination.
- Irrigate wound/s gently with copious amounts of water or saline.
  - Multiple irrigation attempts are usually necessary.
  - Remove visible radioactive foreign bodies (e.g., metallic fragments or shrapnel) using forceps or water-pik.
  - While removing radioactive shrapnel, use long surgical instruments that maximize distance between the operator and the shrapnel.
- Removed foreign bodies and any instruments used to handle foreign bodies should be properly stored in lead containers and labeled by RSO for forensic evaluation and proper disposal.
- 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 wound/s.
  a) Obtain expert medical and health physics advice before excision of vital tissue.
  b) Surgically removed tissue and all surgical supplies should be properly stored and labeled by RSO for forensic evaluation and proper disposal.
- Cover decontaminated wound/s with a waterproof dressing to prevent further contamination.
- Decontaminate skin around wound/s as thoroughly as possible before suturing or other treatment.
- Decontaminate intact skin as described in *Localized Skin Decontamination.*

DECONTAMINATION AND TREATMENT OF BURNS

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 Gray and often is seen with Acute Radiation Syndrome (ARS) but not always.

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

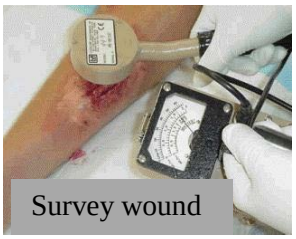
Decontamination of burns with radioactive contamination

- Rinse gently and cover
- Contaminated burns (chemical, thermal) are treated like any other burn
  - Can be managed as one would an open wound
- Exudates will trap most of the contamination
- Contaminants will slough off with the burn eschar

Follow usual protocol for the treatment of burns. Consider consulting a health physicist or RSO for more information about absorption of radionuclides through a burn.

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 run-off during irrigation/decontamination.
Irrigate wound(s) gently with copious amounts of saline or water.
Monitor wound(s) with radiation survey meters (radiation detectors) after each irrigation attempt and record results. ➢ Gently swab wound(s) with sterile cotton-tipped applicator and survey the cotton tip for levels of radioactivity. ➢ If monitoring wound(s) directly, remove contaminated drapes, dressings, etc. before conducting survey.
If contamination levels remain high after primary irrigation attempts, consider conventional surgical debridement of wounds(s) ➢ Obtain expert medical and health physics advice before excision of vital tissue. ➢ Surgically removed tissue and all surgical supplies should be stored properly and labeled by RSO for forensic evaluation and proper disposal.
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 Procedure 2: Localized Skin Decontamination



Survey wound

Drape out wound

Irrigate thoroughly

Catch run-off

LOCALIZED SKIN DECONTAMINATION

Goal of localized skin decontamination: to decrease external contamination to a level of no more than 1000 cpm.

- Perform two decontamination cycles if feasible, with a radiation survey after each cycle.
- Use tepid decontamination water.
- Add mild soap (neutral pH) to water to emulsify and dissolve contamination.
- Direct contaminated waste-water away from patient, rather than over the rest of the body.

Use serial washcloths, gauze pads or surgical sponges to avoid recontamination.

Stop localized skin decontamination efforts after 2 decontamination cycles and handle patient with if the second radiation survey shows:

- External contamination in excess of 1,000 cpm
- Additional external decontamination efforts do not further reduce contamination levels by more than 10%

Attempts to remove all contamination from skin may not be feasible or desirable.

- Some radioactivity may be trapped in outermost layer of skin (stratum corneum) and will remain until normal sloughing occurs (12-15 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/drapes in order to limit spread of contamination to other body sites, immediate environment, and others.
- Treat focal hand contamination not removed after washing by promoting sweating, e.g., put a 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

DECONTAMINATION OF BODY CAVITIES

Uptake of radioactive material may be faster through body orifices and mucous membranes than through intact skin. ➢ Decontaminate contaminated body orifices before decontaminating intact skin but after decontaminating open wounds. ➢ Nasal swab use in large mass casualty incident likely not feasible
Assess carefully that the body cavity is actually contaminated and not the surrounding area.
Perform whole body radiation survey to assess orifice contamination. ➢ Gently swab orifices (ears, nose, mouth) with moistened sterile cotton-tipped applicator and survey swab for levels of radioactivity. See nasal swab information about correlation between nasal swab radioactivity and inhaled lung activity. ➢ For alpha-emitting radioisotopes, swabs must be allowed to dry before assessing for presence of radioactivity. ➢ Localize areas of contamination by radiation survey. ➢ Record initial and follow-up survey results for an individual patient/victim on a body diagram; include name, and time and date of initial and all follow-up radiation surveys. ➢ Update body diagram after each decontamination cycle or use new body diagram for each cycle.
Ear decontamination ➢ Ensure integrity of tympanic membrane (TM) prior to decontamination. ➢ Use ear syringe to rinse external auditory canal only if TM intact. ➢ Sample collected irrigation fluid at frequent intervals for residual radioactivity. ➢ Properly collect, store, and label irrigation fluid for forensic evaluation and proper disposal.
Oral cavity decontamination ➢ Encourage tooth brushing with toothpaste and frequent mouth rinsing. ➢ Encourage gargling with 3% hydrogen peroxide solution for pharyngeal contamination. ➢ Sample collected irrigation fluid at frequent intervals for residual radioactivity.
Properly collect, store, and label irrigation fluid for forensic evaluation and proper disposal.

EYE DECONTAMINATION

➢ Use X-rays to rule out presence of shrapnel in globe
➢ Irrigate eyes gently with copious amounts of saline or water if corneal contamination is present and globe is intact
➢ Do not irrigate a ruptured globe
➢ Direct irrigation stream inner canthus to outer canthus to avoid contamination of the nasolacrimal duct
➢ Collect the fluid used to irrigate eye
o If possible survey collected irrigation fluid at frequent intervals for residual radiation
o If possible, properly collect, store, and label irrigation fluid for forensic evaluation and proper disposal
➢ Observe for onset of conjunctivitis following decontamination

Irrigate gently like this

DO NOT IRRIGATE LIKE THIS

HAIRY AREA DECONTAMINATION

➢ ***DO NOT SHAVE HAIR***
➢ Survey area and record results
➢ Wrap or position the patient to avoid the spread of contamination
➢ Wash area with soap or shampoo (no conditioner) and water
➢ Dry with clean uncontaminated towel
➢ Re-survey
➢ Repeat washing if contamination persists or until no further reduction in

Pregnancy Considerations in a Radiological Emergency

With pregnant patients, general issues to keep in mind:

- Maternal survival is the most important concern in fetal survival
  - Due to the complicated clinical picture a gravida patient with traumatic injuries can present, radiography studies should be considered for treatment clarity as the dose to the fetus is an acceptable risk when the maternal outcome will benefit[3]. The use of CT scans that expose the fetus to higher doses when other options are not available or acceptable should be performed when the survival of the pregnancy or mother is in question.
- Fetal doses due to external radiation exposure are generally less than total dose to the mother due to the fact that the uterine wall and maternal abdominal wall provide shielding to the fetus.
- Fetal doses due to internal contamination are also generally less than total dose to the mother with the except in situations involving isotopes affecting the thyroid (fetal thyroid is actively growing and more iodine sensitive than adult thyroid) or isotopes collecting in the maternal bladder (due to proximity to fetus)
  - For internal contamination counter-measures, pregnant patients should receive priority for treatment for the prevention of long term effects (stochastic effects) in the fetus
- Below a *fetal dose of 5 rem*, there is no significant risk of fetal malformation, reduced IQ or other developmental abnormality. Any pregnant woman exposed to this dose or greater (or suspected to have been) should have specific counseling in consultation with a health physicist and maternal-fetal specialist

EXAMINATION[4] RADIOGRAPHY	**ESTIMATED FETAL DOSE (rem)**	**EXAMINATION** COMPUTED TOMOGRAPHY	**ESTIMATED FETAL DOSE (rem)**
Cervical Spine (AP, lateral)	<0.0001	Head	0
Extremities	<0.0001	Chest (routine)	0.002
Chest (PA, lateral)	0.0002	Chest (pulmonary embolism protocol)	0.02
Thoracic spine	0.0003	Abdomen	0.4
Abdominal (AP) (21cm patient thickness)	0.1	Abdomen and pelvis	2.5
Abdominal (AP) (33 cm patient thickness)	0.3	CT angiography of the aorta	3.4
Lumbar Spine (AP, lateral)	0.1	CT angiography of the coronary arteries	0

[3] RSNA Radiographics May-June, 2014. Volume 34, Issue 3. Constantine et al. page 1

[4] From the table -RSNA Radiographics May-June, 2014. Volume 34, Issue 3. Constantine et al.

Any concerns about the exposure dose to the fetus either from the incident or proposed radiography studies and the mother is not in a life threatened situation, one can consult with a qualified and competent medical physicist or health physicist. They can calculate the actual dose to the fetus and can advise on diagnostic studies, treatment plans, etc. especially prior to any decision concerning continuation of the pregnancy.

Gestational age and radiation dose are important determinants of potential non-cancer health effects. The following points are of particular note:

- **Before about 2 weeks gestation (i.e., the time after conception), the health effect of concern from an exposure of > 0.1 gray (Gy) or 10 rads1 is the death of the embryo. If the embryo survives, however, radiation-induced noncancer health effects are unlikely, no matter what the radiation dose.** Because 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, and the blastocyst will fail to implant in the uterus. Embryos that survive, however, will exhibit few congenital abnormalities.
- **In all stages of gestation, radiation-induced noncancer health effects are not detectable for fetal doses below about 0.05 Gy (5 rads).** Most researchers agree that a dose of < 0.05 Gy (5 rads) represents no measurable noncancer 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 0.05–0.10 Gy (5–10 rads) range for some stages of gestation. However, a practical threshold for congenital effects in the human embryo or fetus is most likely between 0.10–0.20 Gy (10–20 rads).
- **From about 16 weeks' gestation to birth, radiation-induced noncancer health effects are unlikely below about 0.50 Gy (50 rads).** Although some researchers suggest that a small possibility exists for impaired brain function above 0.10 Gy (10 rads) in the 16- to 25-week stage of gestation, most researchers agree that after about 16 weeks' gestation, the threshold for congenital effects in the human embryo or fetus is approximately 0.50–0.70 Gy (50–70 rads).

Surgical Considerations for Patients with Acute Radiation Syndrome and/or External Contamination

If there is a risk of Acute Radiation Syndrome (ARS); total exposure dose unknown:

Suggested treatment sequence for victims of trauma with exposure who are at risk of Acute Radiation Syndrome

1st — Treat life or limb threatening injuries

2nd — Assess patient for Acute Radiation Syndrome†

†Consider early use of granulocyte stimulating cytokines especially if will be going to surgery

3rd — Consider timing of surgery, if possible operate within 48 hours of the event‡

‡ This is especially true if patient is suspected of an exposure of 1 Gray

4th — Remove radioactive shrapnel

5th — Care for open wounds with possible radioactive contamination

If the patient is radioactively contaminated:

Assuming the patient is uniformly contaminated using 2 levels (10 and 100µCi/cm^2- obtain contamination levels from RSO or Heath Physicist) and emitting a constant radiation exposure dose (highly unlikely in a real situation), the following is the time needed for surgical staff standing 20 cm from nearest surface of patient, to reach a dosage of:

1. *5 rem*: Recommended upper limit for healthcare workers in an emergency situation
2. *25 rem*: Recommended upper limit for life saving for first responders; there is very little deterministic risk of health effects; stochastic health effects is a 1% increase in lifetime risk of cancer (~ 28%)

Table calculated assuming a distance of 20 cm between the front surface of the surgeon at mid torso and the nearest surface of the patient with uniform external contamination over entire body[1]

Contamination level on surface of patient		10 µCi per cm2		100 µCi per cm2	
Recommended maximum exposure dose for emergency actions		5 rem	25 rem	5 rem	25 rem
Time near patient for worker to reach recommended maximum exposure dose	Cobalt- 60	13 hrs	64 hrs	77 min	6 hrs
	Iridium- 192	33 hrs	170 hrs	3 hrs	17 hrs
	Cesium- 137	51 hrs	250 hrs	5 hrs	25 hrs
	Americium- 241	760 hrs	3,800 hrs	76 hrs	380 hrs

[1] Health Physics". November 2005, Volume 89, Number 5. Smith, et al.

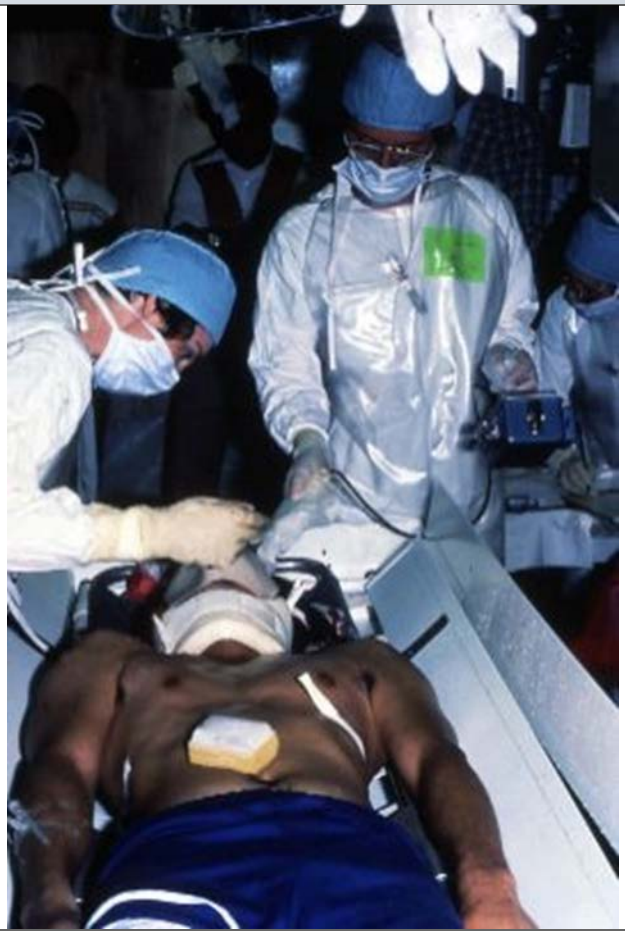
RED/ EMERGENT TREATMENT AREA ACTIONS

OUTSIDE EMERGENCY DEPARTMENT

- Remove external clothing,
- Wrap patient clean sheet, and
- Transfer to clean stretcher prior to entry into ED bypassing decontamination showers

INSIDE RED/EMERGENT TREATMENT AREA

- Continue resuscitation,
- Decontamination simultaneously,
- Survey patient during resuscitation,
- Stabilize patient,
- If patient is admitted begin work up for potential ARS
  - Serial CBCs q 6 hr X 48 hr,
  - Serum Amylase,
  - HCG
- Use results of CBCs to determine total lymphocyte count and lymphocyte depletion
  - Begin 24 hour urine collection for possible bioassay if requested by DOHMH
  - Note times and onset of prodromal symptoms if they occur
- Notify DOHMH about patient and request countermeasures if available.
- If internal contamination is suspected and if isotope is known, and countermeasure available, empirically begin Rx for internal contamination based on Public Health Guidance



RSO surveys patient as staff continues care

YELLOW/URGENT TREATMENT AREA ACTIONS

OUTSIDE EMERGENCY DEPARTMENT
➢ Patient should go through hospital decontamination process prior to entry into Urgent Treatment Area.
INSIDE YELLOW/URGENT TREATMENT AREA
➢ Treat injuries/illness,
➢ Obtain 1st CBC,
➢ Determine risk of internal contamination, o Observe up to 6 hours after event for nausea or vomiting o Obtain second CBCs 4-6 hrs after 1st o Use results to determine total lymphocyte count and lymphocyte depletion o Obtain spot urine for bioassay if requested by public health
➢ If patient is admitted begin work up for potential ARS o serial CBCs q 6 hr X 48 hr, o serum amylase, o HCG o Use results of CBCs to determine total lymphocyte count and lymphocyte depletion o Begin 24 hour urine collection for possible bioassay if requested by DOHMH o Note times and onset of prodromal symptoms if they occur
➢ **Notify DOHMH about patient and discuss countermeasures if available.**
➢ If internal contamination is suspected and if isotope is known, and countermeasure available, empirically begin Rx for internal contamination based on Public Health Guidance.

Manage wounds always as contaminated until proven otherwise

GREEN/MINOR OR NON-INJURED TREATMENT AREA ACTIONS

OUTSIDE EMERGENCY DEPARTMENT
➢ Patient should go through hospital decontamination process prior to entry into Minor Treatment Area.
INSIDE GREEN/MINOR TREATMENT AREA
➢ Treat minor injuries/illness,
➢ Determine risk of internal contamination,
➢ If patient has a significant risk for internal contamination: o Keep patient for ED observation for 4-6 hours prior to discharge, o SEE ED OBSERVATION ACTIONS o Notify DOHMH about patient and discuss countermeasures if available
➢ If patent does not have a significant risk for internal contamination: o Discharge to home or safe location, o Provide any lab results,
➢ Have patient return if vomiting, nausea, bleeding, skin or hair changes occur over the next two weeks o Consider obtaining a CBC in 24 hrs o Consider repeat skin exam in 24 hrs
➢ Patient should have follow up exam in 2-3 weeks with CBC by primary physician

Pregnancy Considerations in a Radiological Emergency

With pregnant patients, general issues to keep in mind:

- Maternal survival is the most important concern in fetal survival
  - Due to the complicated clinical picture a gravida patient with traumatic injuries can present, radiography studies should be considered for treatment clarity as the dose to the fetus is an acceptable risk when the maternal outcome will benefit[3]. The use of CT scans that expose the fetus to higher doses when other options are not available or acceptable should be performed when the survival of the pregnancy or mother is in question.
- Fetal doses due to external radiation exposure are generally less than total dose to the mother due to the fact that the uterine wall and maternal abdominal wall provide shielding to the fetus.
- Fetal doses due to internal contamination are also generally less than total dose to the mother with the except in situations involving isotopes affecting the thyroid (fetal thyroid is actively growing and more iodine sensitive than adult thyroid) or isotopes collecting in the maternal bladder (due to proximity to fetus)
  - For internal contamination counter-measures, pregnant patients should receive priority for treatment for the prevention of long term effects (stochastic effects) in the fetus
- Below a *fetal dose of 5 rem*, there is no significant risk of fetal malformation, reduced IQ or other developmental abnormality. Any pregnant woman exposed to this dose or greater (or suspected to have been) should have specific counseling in consultation with a health physicist and maternal-fetal specialist

EXAMINATION[4] RADIOGRAPHY	**ESTIMATED FETAL DOSE (rem)**	**EXAMINATION** COMPUTED TOMOGRAPHY	**ESTIMATED FETAL DOSE (rem)**
Cervical Spine (AP, lateral)	<0.0001	Head	0
Extremities	<0.0001	Chest (routine)	0.002
Chest (PA, lateral)	0.0002	Chest (pulmonary embolism protocol)	0.02
Thoracic spine	0.0003	Abdomen	0.4
Abdominal (AP) (21cm patient thickness)	0.1	Abdomen and pelvis	2.5
Abdominal (AP) (33 cm patient thickness)	0.3	CT angiography of the aorta	3.4
Lumbar Spine (AP, lateral)	0.1	CT angiography of the coronary arteries	0

[3] RSNA Radiographics May-June, 2014. Volume 34, Issue 3. Constantine et al. page 1

[4] From the table -RSNA Radiographics May-June, 2014. Volume 34, Issue 3. Constantine et al.

Any concerns about the exposure dose to the fetus either from the incident or proposed radiography studies and the mother is not in a life threatened situation, one can consult with a qualified and competent medical physicist or health physicist. They can calculate the actual dose to the fetus and can advise on diagnostic studies, treatment plans, etc. especially prior to any decision concerning continuation of the pregnancy.

Gestational age and radiation dose are important determinants of potential non-cancer health effects. The following points are of particular note:

- **Before about 2 weeks gestation (i.e., the time after conception), the health effect of concern from an exposure of > 0.1 gray (Gy) or 10 rads1 is the death of the embryo. If the embryo survives, however, radiation-induced noncancer health effects are unlikely, no matter what the radiation dose.** Because 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, and the blastocyst will fail to implant in the uterus. Embryos that survive, however, will exhibit few congenital abnormalities.
- **In all stages of gestation, radiation-induced noncancer health effects are not detectable for fetal doses below about 0.05 Gy (5 rads).** Most researchers agree that a dose of < 0.05 Gy (5 rads) represents no measurable noncancer 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 0.05–0.10 Gy (5–10 rads) range for some stages of gestation. However, a practical threshold for congenital effects in the human embryo or fetus is most likely between 0.10–0.20 Gy (10–20 rads).
- **From about 16 weeks' gestation to birth, radiation-induced noncancer health effects are unlikely below about 0.50 Gy (50 rads).** Although some researchers suggest that a small possibility exists for impaired brain function above 0.10 Gy (10 rads) in the 16- to 25-week stage of gestation, most researchers agree that after about 16 weeks' gestation, the threshold for congenital effects in the human embryo or fetus is approximately 0.50–0.70 Gy (50–70 rads).

PERSONAL PROTECTIVE EQUIPMENT (PPE) DONNING GUIDANCE

Donning Personal Protective Equipment
Personnel working in radiation controlled areas should don the following:
1. Scrub suit and gown (cloth or paper) or Tyvek® overalls;
2. For patients not decontaminated: respiratory protection- full-face piece air purifying respirator with a P-100 or High Efficiency Particulate Air (HEPA) filter.
3. For post decon patients: respiratory protection is a fit tested N-95 with a face shield and head/hair covering.
4. Double gloves with inside gloves under arm cuff and secured to gown with heavy tape (duct tape or chemical decontamination suit tape); outer gloves should be easily removable.
5. Head cover or bonnet;
6. Waterproof shoe covers
7. Waterproof aprons or outer gowns for staff using liquids for decontamination or at risk for splash of liquids.
Tape shut all open seams and cuffs using water-resistant heavy tape, such as duct tape or chemical decontamination suit tape.
Assign personal self-reading dosimeters to staff working closest with contaminated patients. Attach to outer garment where they can be easily removed and read.
Dosimeters should be placed near the neck under the surgical gown to avoid gross decontamination. All staff involved in patient care should wear dosimeters.

OSHA/NIOSH PPE recommendations for pre-decontamination care of a patient

Standard Precautions without head covering that is recommended (picture of head covering added)

DOFFING PERSONAL PROTECTIVE EQUIPMENT PROCEDURE

Prior to exiting from a controlled area, personnel begin doffing at the control line, the border between controlled area and clean area, as described below:
1. Remove outer gloves first, turning them inside-out as they are pulled off.
2. Give dosimeter to radiation safety officer or other assigned person (or insure that reading is recorded)
3. Remove all tape at trouser cuffs and sleeves.
4. Remove outer surgical gown, turning it inside-out -- avoid shaking.
5. Remove head cover and mask.
6. Remove shoe cover from one foot and let radiation safety officer or designee monitor shoe; if shoe is clean, step over control line, then remove other shoe cover and monitor other shoe.
7. Remove and discard inner gloves.
8. Conduct total-body radiological survey of each team member.


Step 1


Step 2


Step 3


Step 4


Step 5


Step 6


Step 7

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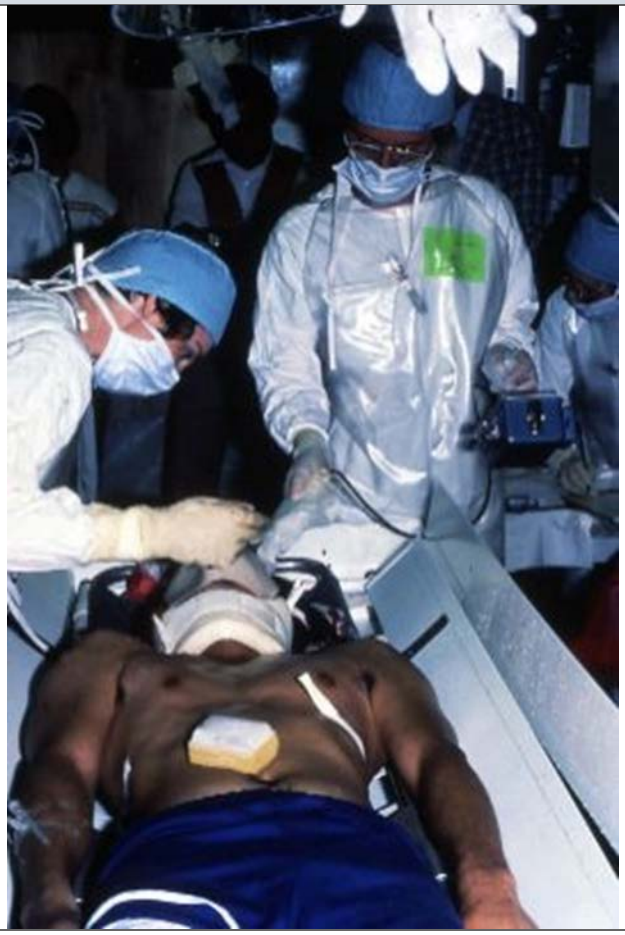

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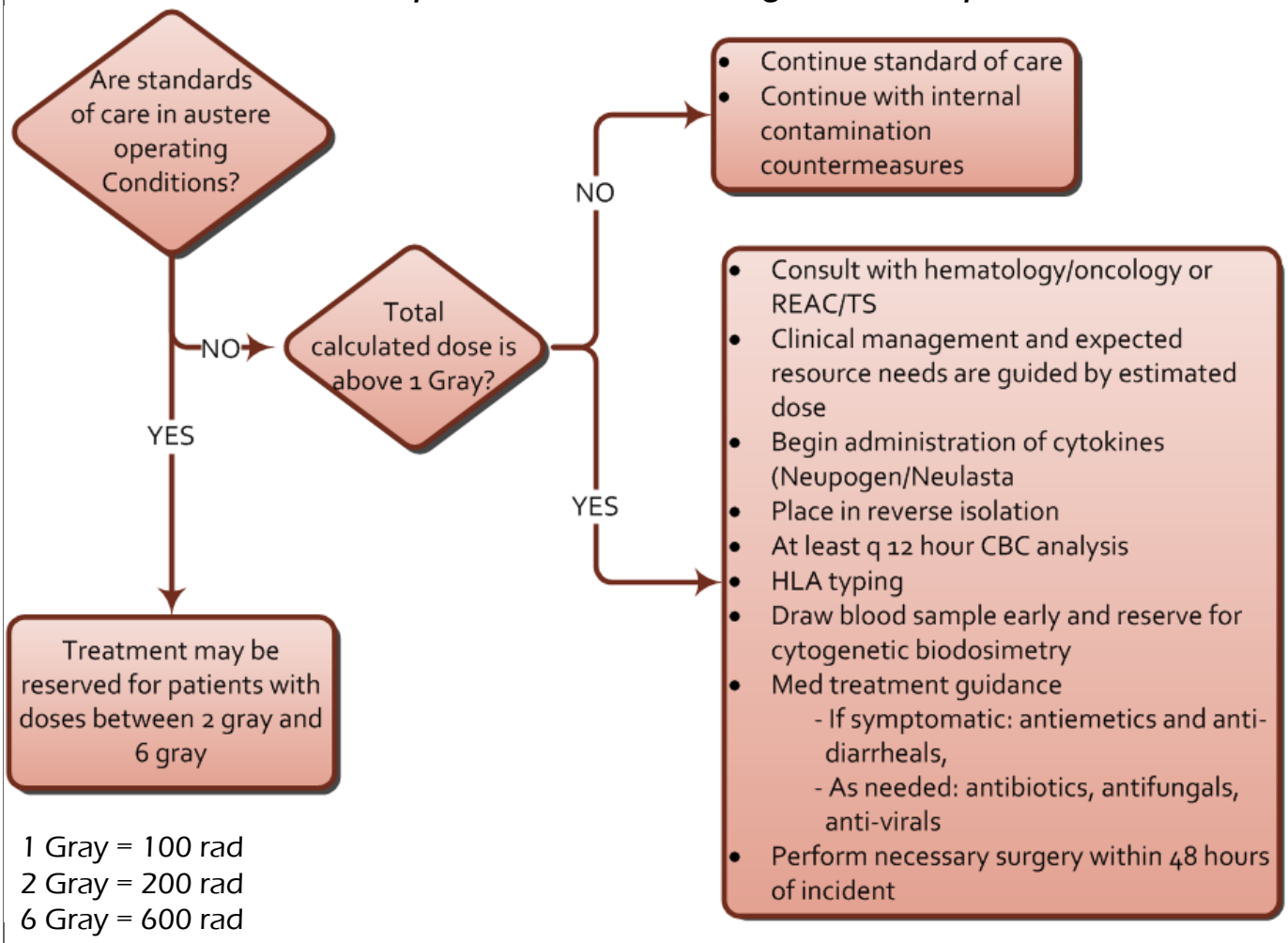
INITIATING INPATIENT ACTIONS FOR ARS AND INTERNAL CONTAMINATION AFTER AN EXPLOSIVE RDD

Recommendations to Diagnose Acute Radiation Syndrome
➢ Observe patient for prodromal symptoms: o Nausea o Vomiting o Fatigue
➢ If symptoms occur, record time of onset and severity
➢ Draw CBCs q 4 to 6 hours for a total of 3 CBCs in the first 12 to 24 hours following exposure (the lymphocyte count will decrease with a significant exposure)
➢ Enlist the aid of radiation biological effect knowledgeable people to estimate dose (NYC DOHMH; NYS DOH; REAC/TS; CDC)

Actions to take when patient has had a significant exposure



1 Gray = 100 rad
2 Gray = 200 rad
6 Gray = 600 rad

Surgical Considerations for Patients with Acute Radiation Syndrome and/or External Contamination

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Suggested treatment sequence for victims of trauma with exposure who are at risk of Acute Radiation Syndrome

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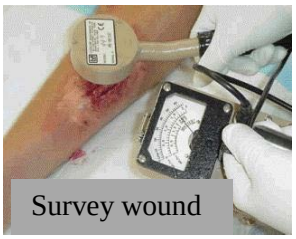
MANAGING OPEN WOUNDS

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 run-off during irrigation/decontamination.
Irrigate wound(s) gently with copious amounts of saline or water.
Monitor wound(s) with radiation survey meters (radiation detectors) after each irrigation attempt and record results. ➢ Gently swab wound(s) with sterile cotton-tipped applicator and survey the cotton tip for levels of radioactivity. ➢ If monitoring wound(s) directly, remove contaminated drapes, dressings, etc. before conducting survey.
If contamination levels remain high after primary irrigation attempts, consider conventional surgical debridement of wounds(s) ➢ Obtain expert medical and health physics advice before excision of vital tissue. ➢ Surgically removed tissue and all surgical supplies should be stored properly and labeled by RSO for forensic evaluation and proper disposal.
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 Procedure 2: Localized Skin Decontamination



Survey wound

Drape out wound

Irrigate thoroughly

Catch run-off

ED OBSERVATION FOR ACUTE RADIATION ILLNESS PRODROME

The goal of ED observation is to have enough time to evaluate patients who may have a risk of significant radiation exposure and, therefore, a risk of developing acute radiation syndrome symptoms.

Observe patients who are:

1. *Are being considered for discharged, and*
2. *Have a risk of internal contamination or significant exposure by answering YES to any of the following questions:*
   - a. Did they have injury or illness due to event?
   - b. Were they a first responder without respiratory PPE?
   - c. Did they have a penetrating injury or contaminated wound with radioactive material?
   - d. Did they have prolonged extrication from event, especially relevant if they did not have respiratory protection during this time?
   - e. Did they have prolonged transit time, or spend prolonged time in the immediate area around event (bystanders rescuing others, e.g.), especially if they did not have respiratory protection during this time?; and,
   - f. Have they had any history of nausea, vomiting, fatigue, or diarrhea within hours after the event?

Observation steps:

1. Observe up to 6 hours after event for nausea or vomiting
2. Obtain two CBCs 4-6 hrs apart
3. Use results to determine total lymphocyte count and lymphocyte depletion
4. Obtain spot urine for bioassay if requested by public health
5. Consider beginning outpatient treatment for Internal Contamination based on history
6. Contact NYC DOHMH about all patients being observed

DISCHARGE CONSIDERATIONS AFTER A RADIOLOGICAL INCIDENT

➢ Discharge to home; provide any lab results and results of radiation surveys,
➢ If patient has no evidence of radiation contamination at time of discharge, please print that clearly on discharge instructions,
➢ Advise patient to return to ED if vomiting, nausea, bleeding, skin or hair changes.
➢ Provide instructions for wound care or other injury illness,
➢ Consider obtaining a CBC in 24 hrs,
➢ Consider repeat skin exam in 24 hrs,
➢ Patient should have follow up exam in 2-3 weeks with CBC by primary physician, and,
➢ Insure that records for patient include current contact information.

Detonation of a Radiological Dispersal Device *on site situation report*

- Have gamma emitters been identified?
- Are there areas with significant dose rates of greater than 10 R/hr?
- Did patient have a long extraction time?
- Was the patient heavily contaminated?

If yes to above then external exposure from groundshine needs to be added to total exposure dose (with internal contamination dose and exposure from skin contamination with gamma emitters)

For a Total Body Dose < 2 Gy

- Prodrome: 10% to 50% of patients will have onset of vomiting 2 hours post exposure; patients with less than 0.75 Gy will likely not experience nausea and vomiting
- Outpatient management may be appropriate for 2 Gray or less exposure if patient does not have significant concurrent chronic illness especially if they are not immunocompromised prior to exposure.