Chapter 28

Radiological Injuries

The reader is strongly advised to supplement material in this chapter with the following two references:

1. Armed Forces Radiobiology Research Institute. *Medical Management of Radiological Casualties*. 4th ed. Bethesda, MD: AFRRI; July 2013.
2. Waselenko JK, MacVittie TH, Blakely WF, et al. Medical management of the acute radiation syndrome: recommendations of the Strategic National Stockpile Radiation Working Group. *Ann Intern Med*. 2004; 140:1037–1051.

Introduction

Radiological casualties on the battlefield may occur with improvised or conventional nuclear devices or radiological dispersal devices (“dirty bombs”) (Table 28-1).

- Conventional nuclear weapons.
  - The relative casualty-causing potential depends primarily on four factors:
    - Yield of the weapon.
    - Height of burst.
    - Environmental conditions in which the detonation occurs.
    - Distribution and shielding of troops in the target area.
  - A nuclear detonation generally causes injuries with the following distribution:
    - Blast injury: 50%.
    - Thermal injury: 35%.
    - Ionizing radiation injury.
      - Initial: 5%.

        ◊ Residual: 10%.

- A radiological dispersal device (RDD) is any device—including any weapon or equipment—other than a nuclear explosive device, specifically designed to spread radiation.
    - RDDs contaminate conventional casualties with radionuclides, complicating medical evacuation.
    - RDDs are ideal weapons for terrorism, and are used to intimidate and deny access to an area by spreading radioactive material.

Table 28-1. Radiological Casualties

Weapon Effect	Weapon Yield (kt)/Distance (m)			
	1 kt	**10 kt**	**100 kt**	**1,000 kt**
Blast (50% casualties)	140 m	360 m	860 m	3,100 m
Thermal radiation (50% deep burns)	370 m	1,100 m	3,190 m	8,020 m
Ionizing radiation (50% immediate transient ineffectiveness)	600 m	950 m	1,400 m	2,900 m
Ionizing radiation (50% lethality)	800 m	1,100 m	1,600 m	3,200 m

kt: kiloton; m: meter.

Triage

- Triage should be conducted on traditional surgical and medical considerations, then modified by radiation injury level.
    - Radiation interacts deleteriously with trauma. Patients with medical or traumatic injury who also have whole-body or significant partial-body irradiation have a substantially worse prognosis and will require a higher triage priority.
    - Make a preliminary diagnosis of radiation injury only for those with exposure symptoms, such as nausea, vomiting, diarrhea, fever, ataxia, seizures, prostration, and hypotension.
    - Radiation patient triage classifications.
        - ♦ **Immediate:** Those requiring immediate lifesaving intervention. Pure radiation injury is not acutely life-threatening unless the irradiation is massive. If a

massive dose has been received, the patient is classified as <u>expectant</u>.

- ♦ **Delayed:** Casualties with only radiation injury, without gross neurological symptoms (ataxia, seizures, and impaired cognition). For trauma combined with radiation injury, all surgical procedures must be completed within 36–48 hours of radiation exposure, or delayed until at least 2 months after the injury.
- ♦ **Minimal:** Buddy care is particularly useful here. Casualties with radiological injury should have all wounds and lacerations meticulously cleaned and then closed.
- ♦ **Expectant:** Receive appropriate supportive treatment compatible with resources; large doses of analgesics as needed.

- Table 28-2 provides medical aspects of radiation injuries.

Table 28-2. Medical Aspects of Radiation Injuries

Probability/degree of exposure	Signs and Symptoms: Nausea	Vomiting	Diarrhea	Hyperthermia	Erythema	Hypotension	CNS dysfunction
Unlikely	–	–	–	–	–	–	–
Probable	++	+	+/–	+/–	–	–	–
Severe	+++	+++	+/+++	+/+++	–/++	+/++	–/++

CNS: central nervous system.

- The lethal dose (LD) of radiation, which will kill 50% of a population within 60 days of exposure, is called $LD_{50/60}$. The $LD_{50/60}$ is approximately 3–4 Gy for a population with radiation injury alone and with no significant medical care. The $LD_{50/60}$ for a population with radiation injury alone and the best available medical care (including antiemetics, antivirals, antibiotics, hematopoietic cytokines, and transfusion) may be 6 Gy or more. Combined injuries with radiation and trauma and/or burns will markedly lower the LD_{50}.

- Significant medical care may be required at 3–5 weeks for 10%–50% of personnel. Anticipated problems should include infection, bleeding, fever, vomiting, and diarrhea. Wounding or burns will markedly increase morbidity and mortality.
- Treatment.
  - Fluid and electrolytes for gastrointestinal losses.
  - Cytokines for immunocompromised patients (follow granulocyte counts).
  - Restricted duty. No further radiation exposure, elective surgery, or wounding. May require delayed evacuation from theater during nuclear war in accordance with command guidance.
  - If there are more than 1.7×10^9 lymphocytes per liter, 48 hours after exposure, it is unlikely that an individual has received a fatal dose.
  - Patients with low (300–500) or decreasing lymphocyte counts, or low granulocyte counts, should be considered for cytokine therapy and biological dosimetry using metaphase analysis where available.
- Asymptomatic patients with lethal radiation dose may perform usual duties until symptomatic.

Potential Injuries

- **Thermal/flash burns** or thermal pulse burns are caused directly by infrared radiation. Close to the fireball, the thermal output is often so great that everything is incinerated, and even at great distances, thermal/flash burns will occur (see Chapter 26, Burns, for management).
  - Burn mortality rates associated with radiation exposure are significantly higher due to bone marrow suppression and infection (a 50% total body surface area burn associated with radiation exposure has a mortality of 90%).
- **Blast injuries** consist of two basic types of blast forces that occur simultaneously in a nuclear detonation blast wave: (1) direct blast wave overpressure forces, measured in terms of atmospheres of overpressure; and (2) indirect blast wind drag forces, normally measured in the velocities of the winds that cause them. The most important blast effects are those due to the blast wind drag forces.

- **Direct blast wave overpressure forces.** When the blast wave acts directly upon a resilient target such as the human body, rapid compression and decompression result in transmission of pressure waves through the tissues. These waves can be quite severe and will result in damage primarily at junctions between tissues of different densities (bone and muscle) or at the interface between tissue and air spaces (lung tissue and the gastrointestinal [GI] system). Perforation of the eardrums is a common blast injury.
- **Indirect blast wind drag forces.** The drag forces of blast winds are proportional to the velocities and duration times of these winds, which in turn vary with distance from the point of detonation, yield of the weapon, and altitude of the burst. These winds are relatively short in duration but are extremely severe and may reach several hundred kilometers per hour. Indirect blast injuries occur as crush and/or translational injuries and as missile injuries. Casualties are likely to be thrown against immobile objects and impaled by flying debris.

- **Radiation injuries** are due to ionizing radiation released both at the time of the nuclear detonation and for a considerable time afterward. The two types of radiation released are electromagnetic (gamma) radiation and particulate (alpha, beta, and neutron) radiation.
  - Alpha particles can be shielded against by clothing.
  - Beta particles shielding requires solid materials, like a wall.
  - Gamma and neutron radiation are the most biologically active and require lead equivalent shielding for protection.
  - Fission products are the major radiation hazard in fallout because a large number emit penetrating gamma radiation. This can result in injuries, even at great distances.
  - Fallout causes whole-body irradiation from gamma-emitting isotopes because they do not actually have to be on a person's skin to cause damage.
- **Flash blindness** may occur as the result of a sudden peripheral visual observation of a brilliant flash of intense light energy.
- **Retinal burns** may also occur, and result in scarring and permanent altered visual acuity.

Treatment of Combined Injuries

- Following the detonation of a nuclear device, the majority of resulting casualties will have sustained a combination of blast, thermal, and radiological injuries.
- The usual methods of treatment for blast injuries must be modified in those casualties simultaneously exposed to ionizing radiation.

Traditionally, combat wounds are left open. However, wounds left open to heal by secondary intention in the irradiated patient will serve as a nidus of infection. <u>Wounds exposed to ionizing radiation should be debrided and closed at a second-look operation within 36–48 hours.</u>

- Hypotension should always be assumed to be hypovolemia and not due to radiological injury.
- Hyperthermia is common.
- Radiological injuries increase the morbidity and mortality of injuries due to compromise of the normal hematopoietic and immune responses to injury. Surgical procedures may need to be delayed during bone marrow suppression, if at all possible.
- Potassium iodide may be used for prevention of thyroid uptake of radioisotopes after nuclear reactor accidents.
- Chelating agents may be used to eliminate metals from the bloodstream before they reach target organs.
- Mobilizing agents are used to increase the excretion of internal contaminants.
- Prussian blue is used to remove radionuclides from the capillary bed surrounding the intestine and prevents their reabsorption. Delay until patient is stable. Treat ABCs first.

Decontamination

- There are no reports of healthcare provider injury with radiation while performing ABCs on a radiation victim.
- Removal of the casualty's clothing can eliminate as much as 90% of the radiological contamination.
- The first priority of surface decontamination should be to open wounds, then other areas.

- o To prevent rapid incorporation of radioactive particles, wounds should be copiously irrigated with normal saline for several minutes.
- o The eyes, ears, nose, mouth, and areas adjacent to uncontaminated wounds, hair, and remaining skin surface should be decontaminated with soap and water.
- o Personnel providing decontamination must protect themselves from ionizing radiation exposure with:
  - ♦ Protective outer clothing.
  - ♦ Aprons, gloves, and masks.
- Amputation should be seriously considered when the contamination burden is great and severe radionecrosis is likely.

Logistics of Casualty Management

- **If nuclear weapons are employed within theater, the entire medical evacuation and treatment system will be severely overburdened,** and some system of classification and sorting of casualties must be added to the normal procedures of evacuation and hospitalization.
- Patients entering a medical treatment facility should be routinely decontaminated if monitoring for radiation is not available.
- These two requirements—the sorting of casualties and the holding of excess numbers—must be planned for and drilled as part of the normal organization and operation of the health service support system in a theater of operations where radiation exposure potential is high.

For Clinical Practice Guidelines, go to
http://jts.amedd.army.mil/index.cfm/PI_CPGs/cpgs