Chapter 30

Radiological Injuries

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

1. ***Medical Management of Radiological Casualties Handbook*, 2003, Armed Forces Radiobiology Research Institute, Bethesda, MD.**
2. ***Medical Management of the Acute Radiation Syndrome: Recommendations of the Strategic National Stockpile.* Radiation Working Group, Strategic National Stockpile (*Annals of Internal Medicine*, 15 June 2004).**

Introduction

Radiological casualties on the battlefield may occur with improvised or conventional nuclear devices or radiological dispersal devices ("dirty bombs") (Table 30-1).

- 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.
  - o RDDs contaminate conventional casualties with radionuclides, complicating medical evacuation.
  - o RDDs are ideal weapons for terrorism and are used to intimidate and deny access to an area by spreading radioactive material.

Table 30-1. Radiological casualties.

Weapon Effect	Weapon Yield (Kiloton)/Distance (Meters)			
	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

Triage

- Different from conventionally injured patients, because survivable radiation injury is not manifested until days to weeks after exposure.
  - o **Based primarily on conventional injuries**, then modified by radiation injury level.
  - o Make a preliminary diagnosis of radiation injury only for those with exposure symptoms, such as nausea, vomiting, diarrhea, fever, ataxia, seizures, prostration, hypotension.
  - o Radiation patient triage classifications.
    - ♦ **Delayed:** casualties with only radiation injury, without gross neurological symptoms (ataxia, seizures, 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.

- **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 Expectant.
- **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 30-2 provides medical aspects of radiation injuries.

Table 30-2. Medical aspects of radiation injuries.

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

The lethal dose 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 Gray (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.
  - o Fluid and electrolytes for GI losses.
  - o Cytokines for immunocompromised patients (follow granulocyte counts).
  - o Restricted duty. No further radiation exposure, elective surgery, or wounding. May require delayed evacuation from theater during nuclear war IAW command guidance.
  - o If there are more than $1.7 \bullet 10^9$ 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 28, Burns, for management).
  - o Burn mortality rates associated with radiation exposure are significantly higher due to bone marrow suppression and infection (a 50% TBSA burn associated with radiation exposure has a mortality of 90%).
- **Blast injuries** associated with a nuclear detonation include:
  - o Direct blast wave overpressure forces measured in terms of atmosphere overpressure.
  - o Indirect blast wind drag forces, measured in terms of wind velocity, which may displace large objects such as vehicles or cause the collapse of buildings.

- **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.
  - o Alpha particles can be shielded against by clothing.
  - o Beta particles shielding requires solid materials, like a wall.
  - o Gamma and neutron radiation are the most biologically active, and require lead equivalent shielding for protection.
  - o 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.
  - o 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 radiologic 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
- No healthcare provider has ever been injured with radiation while performing ABCs on a radiation victim.
- Removal of the casualty's clothing can remove as much as 90% of the radiological contamination.
- The first priority of surface decontamination should be to open wounds, then other areas.
  - To prevent rapid incorporation of radioactive particles, wounds should be copiously irrigated with normal saline for several minutes.
  - The eyes, ears, nose, mouth, areas adjacent to uncontaminated wounds, hair, and remaining skin surface should be decontaminated with soap and water.
  - 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 the 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 the 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.