RADIATION INJURY

Types of Radiation Injury
Regardless of where or how an accident involving radiation happens, three types of radiation induced injury can occur: external irradiation, contamination with radioactive materials, and incorporation of radioactive material into body cells, tissues, or organs.

External Irradiation
External irradiation occurs when all or part of the body is exposed to penetrating radiation from an external source. During exposure this radiation can be absorbed by the body or it can pass completely through. A similar thing occurs during an ordinary chest x-ray. Following external exposure, an individual is not radioactive and can be treated like any other patient.

Contamination
The second type of radiation injury involves contamination with radioactive materials. Contamination means that radioactive materials in the form of gases, liquids, or solids are released into the environment and contaminate people externally, internally, or both. An external surface of the body, such as the skin, can become contaminated. These victims pose a threat to health care providers and must be decontaminated. If radioactive materials get inside the body through the lungs, gut, or wounds, the contaminant can become deposited internally.

Incorporation
The third type of radiation injury that can occur is incorporation of radioactive material. Incorporation refers to the uptake of radioactive materials by body cells, tissues, and target organs such as bone, liver, thyroid, or kidney. In general, radioactive materials are distributed throughout the body based upon their chemical properties. Incorporation cannot occur unless contamination has occurred.

Severity of Injury
In general, the higher the dose, the more severe the early effects will be and the greater the possibility of delayed effects. Obviously, one can increase the dose until the cell is killed outright. However, it is found that a much lower dose can stop cell division.

For example, if we consider the hematopoietic system, an individual hematopoietic stem cell has the capability of producing millions of mature cells. Preventing stem cell division means the loss of these cells. The importance of this is that a sub-lethal dose produces these effects.

Two important organ systems that have rapidly dividing cell lines are the hematopoietic and gastrointestinal systems.

After the dropping of the atomic bombs in Japan, experiments were carried out on various animals to determine the dose that would kill 50 percent of the experimental animal population within a set time period. Accident data on humans that were not treated indicate the lethal dose (LD) 50 was in the region of 350 rads to 450 rads.

Acute Radiation Syndrome (ARS)

Definition
An acute illness, which follows a roughly predictable course over a period of time ranging from a few hours to several weeks after exposure to ionizing radiation. The acute radiation syndrome is produced if enough radiation reaches enough sensitive tissue. Important factors are:

- High dose
- High dose rate
- Whole body exposure

- Penetrating irradiation

Signs and Symptoms
The signs and symptoms that develop in ARS occur through four distinct phases:

Prodromal phase
Depending on the total amount of radiation absorbed, patients may experience a variety of symptoms including loss of appetite, nausea, vomiting, fatigue, and diarrhea. After high radiation doses, additional symptoms such as prostration, fever, respiratory difficulties, and increased excitability may develop. This is the stage at which most victims seek medical care.

Latent phase
This is the transitional period in which many of the initial symptoms resolve, and may last for up to 3 weeks depending on the original radiation dose. This time interval decreases as the initial dose increases.

Illness phase
The period of time when overt illness develops, often characterized by infection, bleeding, electrolyte imbalance, diarrhea, changes in mental status, and shock.

Recovery or death phase
This follows the period of overt illness, which may take weeks or months to resolve.

AFFECTED SYSTEMS

Hematopoietic or Blood Forming System
This system shows the earliest indication of the severity of the radiation exposure through the rapidity and degree of drop in the cell count (lymphocytes, granulocytes, thrombocytes, and reticulocytes). This reduction in the cell count is commonly associated with fever, sepsis, and hemorrhagic complications.

The absolute lymphocyte count at 48 hours after exposure is a good predictor for prognosis. For example, if the total lymphocyte count is greater than 1,200 it is unlikely that the patient has received a lethal dose. If at 48 hours the lymphocyte cell count is between 300 and 1,200, a significant exposure has occurred and the patient should be hospitalized with barrier protection isolation. Lymphocyte levels of less than 300 cells per/ml are usually critical and warrant the consideration of the use of colony-stimulating factors on an individual basis.

Gastrointestinal System
Symptoms in this system are regularly seen at acute doses greater than 600 rads and result from damage to the epithelial cells lining the intestinal tract. The higher the exposure, the sooner the symptoms of nausea and vomiting develop. The presence of these symptoms typically overlaps with the drop in the cell count described previously. As a result, sepsis, loss of fluids, electrolytes and opportunistic infections complicate the picture. Persistent high fevers and bloody diarrhea is an ominous sign despite fluid and electrolyte replacement.

Central Nervous System (CNS)
Central nervous system symptoms are seen with acute radiation doses in excess of 1000 rads and are probably due to diffuse microvascular leaks within the brain. Damage to these blood vessels result in the loss of fluids and electrolytes, edema, increased intracranial pressure, and death. This injury is irreversible and the victim rarely lives long enough to suffer any hematological or gastrointestinal symptoms. Symptoms of shock may develop quickly in these patients. There is also associated cardiovascular collapse in this kind of patient.

Integumentary
Various skin changes occur depending on the radiation dose. The injuries tend to progress with dose level and there appears to be a threshold effect for these clinical signs. Early erythema is an important sign to look for. At doses around 300 rads, erythema will develop within a few hours, but more importantly, it can disappear within a few hours only to reappear at a later time. Therefore, the patient should be examined on an hourly basis for this sign and ideally photographs should be taken to document this sign. If local radiation dermatitis develops with this sign, the dose is in the region of 1,000 rads. If blistering occurs then the dose is in the range of 1,500 rads. Also if necrosis develops, the dose is in the region of greater than 5,000 rads. Therefore, by noting these clinical signs, one is able to establish the approximate dose range the patient was subjected to and these doses would be confirmed by dosimetry at a later stage.

>300 rads: Epilation 17-21 days
>600 rads: Erythema that may disappear within a few hours
>1000 rads: Dry desquamation 2 - 4 weeks
>1500 rads: Moist desquamation 2 - 8 weeks
>5000 rads: Necrosis few days to months

Trauma and Radiation
Patients who have suffered trauma (from an explosive or burn) combined with an acute exposure to penetrating radiation will have an increased chance of dying as compared to patients who have suffered from the same dose of radiation without trauma. All combined injuries are worse than radiation alone. If a patient has received an acute dose greater than 200 rads, effort must be made to close wounds, cover burns, reduce fractures, and perform surgical stabilizing and definitive treatments within the first 48 hours after injury. After 48 hours, surgical interventions should be delayed for 2 to 3 months.

Triage of Radiation Casualties
Triage of victims from a radiological event should follow the same principles used in sorting victims of a hazardous material incident. Victims are classified with regard to their need for treatment and will be classified as requiring minimal treatment, immediate care, delayed care, or as expectant. Since the degree of radiation injury will not be initially apparent, triage criteria will need to be based on associated injuries and complaints. The triage method used will vary according to local practices.

Patients who require immediate attention are those with traumatic injuries such as crushing extremity wounds, incomplete amputations, severe burns of face and upper respiratory tract, and difficulty breathing due to mechanical problems. Delayed casualties include those with traumatic injuries that are not life threatening such as simple fractures, or second and third degree burns less than 25 percent of body surface area (BSA).

Minimal casualties are those with burns less than 10 percent of BSA, but not involving critical areas or those who have received short□term body ionizing radiation doses of 100 to 150 rads. When this dose of irradiation is combined with burns, then the prognosis is much more severe.

Expectant casualties have severe burns greater than 30 percent BSA, critical injuries to the respiratory or nervous system, or have received lethal doses of total body radiation, as indicated by a combination of clinical signs, including high fever, disorientation, bloody diarrhea, or vomiting.

Classification, Treatment, and Disposition
Once the radiological survey and decontamination procedure is complete, patients may be classified into one of 3 categories, based on their presenting signs and symptoms.

Survival Probable Group
This group of patients who present without any initial symptoms, or whose symptoms are so minimal (i.e., nausea and vomiting), that they resolve in a few hours. These individuals have most probably not received a lethal radiation dose, and most likely are exposed to < 100 rads. The initial CBC and sequential studies will not show a significant decrease in the lymphocyte or granulocyte counts. These patients can be safely sent home and instructed to return if symptoms redevelop.

Survival Possible Group
These victims present with nausea and vomiting, which typically last 24 to 48 hours followed by an asymptomatic period. During this latent phase, laboratory evaluations will show a drop in various cell counts (lymphocytopenia, leukocytopenia, and thrombocytopenia). If vomiting is severe, these patients should be admitted for fluid and electrolyte therapy and treated with antiemetics.

If the absolute lymphocyte count is less that 1,200 (or 50 percent of the baseline), protective isolation precautions should be implemented. These patients will have typically received a radiation dose in the range of 200 to 800 rads. The LD50 in mass casualty situations is in the range of 350 to 450 rads. Treatment is primarily supportive.

Blood replacement products, hyperalimentation, antibiotics, antivirals, and antifungal medications should only be administered after consultation with a hematologist, oncologist, or infectious disease specialist. Colony-stimulating factors will probably be indicated for pancytopenia.

Survival Improbable Group
Patients in this group have been exposed to whole-body irradiation in doses exceeding 800 rads. These victims present an acute onset of fulminating vomiting, diarrhea, and shock, requiring aggressive fluid and electrolyte therapy. The presence of any CNS symptoms (confusion, a change in mental status, etc.) signals that the patient has received a lethal dose of radiation. These victims will develop bone marrow suppression, leading to aplasia and pancytopenia that is uniformly fatal unless a successful hematopoietic stem cell transplant and/or colony stimulating factors are used. Treatment outcomes in some recent accidents suggest that exposure in the 800 to 1,200 rad range can be successfully managed through the hematopoietic crisis, although the individuals treated often succumbed to residual lung damage 6 to 12 months following exposure. In mass casualty situations, these victims are provided with comfort measures only (i.e., pain management).

Treatment
Since no antidote exists for radiation exposure, treatment is primarily supportive with more specialized care directed towards patients with high dose irradiation and those with internal contamination. Consultation with specialists in hematology, oncology, radiation, and infectious disease should be obtained.

The need for initial treatment for internally contaminated patients is determined based on the patient's medical condition, history, biological samples (nasal swabs), and definitive evaluation of internal contamination. Whole body counting may be needed if internal contamination is suspected.

MEDICATIONS AND MECHANISMS OF DECORPORATION
(Modified Form Safety Series 47, IAEA)

Radionuclide	Medication	Ingestion/Inhalation	Wound	Principle of Action
Iodine	KI	130 mg (tab.) stat, followed by 130 mg q.d. x 7 if indicated	Same	Blocking
Rare earths Plutonium Transplutonics Yttrium	DTPA	1 gm Ca-DTPA in 500ml 5 percent D/W IV over 60 min; or 1 gm (4ml) in 6 ml 5 percent D/W by slow IV injection (1 min)		Chelation
Polonium Mercury Arsenic Bismuth Gold	BAL	One ampule (=300 mg) IM q 4 hrs for 3 days - (first test for sensitivity with 3 amp.)	Same	Promotes excretion
Uranium	Bicarbonate	Slow IV infusion of bicarbonated physiological solution (250 ml at 14 percent)	Slow IV infusion of bicarbonated physiological solution (250 ml at 14 percent) and wash with bicarbonate	Alkalinization of urine; reduces chance of ATN
Cesium Rubidium Thallium	Prussian Blue [Ferrihexacyano-Ferrate(II)]	1 gm in 100-200 ml water p.o. t.i.d. for several days	Same	Mobilization from organs and tissues - reduction and absorption
Radium	Ca-gluconate	May be tried; 20 percent Ca-gluconate 10 ml IV once or twice daily	Same	Displacement
Strontium	Ammonium chloride	3 gm t.i.d. p.o.	Same	Demineralizing agent
Tritium	Water	Force liquid	Same	Isotopic dilution
Strontium Radium	$BaSO_4$	100 gm BaSO4 in 250 ml of water	Same	Reduces absorption
Calcium Barium	Sodium Alignate	10 gm in a large glass of water	Same	Inhibits absorption
Copper Polonium Lead Mercury Gold	D-penicillamine	1 gm IV q.d. or 0.9 gm p.o. 14 - 6 hours	Same	Chelation