

Hospital Triage in the First 24 Hours after a Nuclear or Radiological Disaster Berger, ME; Leonard, RB; Ricks, RC; Wiley, AL; Lowry, PC; Flynn, DF

Abstract: This article addresses the problems emergency physicians would face in the event of a nuclear or radiological catastrophe. It presents information about what needs to be done so that useful information will be gathered and reasonable decisions made in the all important triage period. A brief introductory explanation of radiation injury is followed by practical guides for managing the focused history, physical exam, laboratory tests, initial treatment, and disposition of victims of acute radiation syndrome and combined injury. The guides are not intended to serve as a hospital's "emergency plan," although the guidance can provide supplementary information for hospital planning.

Introduction:

Emergency personnel are rarely familiar with the topics of radiation exposure and/or radioactive contamination, and few emergency physicians have experience in managing a case of acute radiation syndrome or local radiation injury. Although many emergency personnel have had training regarding procedures for handling the patient contaminated with radioactive materials, most training has focused on the more likely situation of handling only one or two accident patients. Sadly, today's international environment is such that the real possibility exists that emergency department personnel might have to deal with not just one or two victims of a radiation accident, but overwhelming numbers injured in a malevolent act. Table 1 provides information about types of catastrophes involving radiological or nuclear materials.

Triage and distribution of patients to distant hospitals would be a necessity should such a malevolent act occur. Victims could be irradiated, contaminated with radioactive materials and injured by the heat and force of explosions. On-scene triage, (not covered in this article), should be based on the severity of conventional injuries, while triage during the first 24 hours of hospitalization should include consideration of exposure to penetrating radiation. Although irradiation does not cause early, life-threatening symptoms, it can, in time, cause serious or life-threatening illness if the radiation dose is high. If irradiation is combined with trauma, recovery is threatened. Triage and subsequent early treatment decisions are based on the signs and symptoms evident in the first 24 to 48 hours and on the results of laboratory tests completed during that time. This article gives information about what needs to be done in the first 24 hours so that essential information is gathered and reasonable decisions can be made.

Types of Radiation Injury

Irradiation: Irradiation (sometimes called "exposure") occurs when a person is exposed to penetrating radiation (gamma rays, neutrons, x-rays) from a source external to the body. The total body or a large portion of it can be irradiated in an incident, or a small,

localized area can be affected. Time, distance, and shielding can reduce exposure from a source (see Table 2). Once the source of penetrating radiation is removed, or the victim is moved away from the source, no further exposure will occur.

Irradiation of the whole body or a significant part of it can result in acute radiation syndrome. Acute radiation syndrome begins with a prodrome that starts after exposure and lasts 24 to 48 hours. During this prodrome, the kind and severity of symptoms and their timing is dependent on the total amount of energy deposited in the body (i.e., the dose), the dose rate, and the volume and location of involved tissue. The prodromal period is followed by a symptom-free latent period lasting a few hours when exposures are high, or as long as two or three weeks or more for lower levels of exposure. A period of manifest illness follows, with the type of symptoms and their severity dependent on radiation dose. Dose is measured in “rads,” (or, in SI units, in Grays. One hundred rads = 1 Gray). The LD 50/60, without treatment, is estimated to be 350 rads, or 3.5 Grays.¹ In general, loss of stem cells and rapidly dividing cells from hematopoietic, gastrointestinal, and other tissues can lead to bleeding, infection, diarrhea, mucositis, skin lesions and other problems, followed by recovery or death.

The symptoms occurring in the first 24 hours after a total or partial body exposure are seldom life-threatening. Examples of these are nausea, vomiting, fatigue, headache, diarrhea, parotitis, erythema, and fever. However, loss of fluids and electrolytes can be problematic in infants, children, and the elderly; in addition, some *lethal* exposures have resulted in severe hypotension.

Early symptoms of a localized skin injury from contact with a small but highly radioactive source of penetrating radiation include itching, tingling, erythema, and edema. Lesions do not appear for days to weeks. Unless symptomatic, *emergency care is not needed urgently*. However, these lesions can be debilitating and life threatening, and a significant amount of medical care could be forthcoming. If resources are sufficient, a baseline CBC and differential should be completed and repeated in 24 hours. Medical follow-up is essential, and victims should be cautioned to avoid trauma to involved areas.

Contamination: External contamination occurs when radioactive materials are deposited on the external surface of the body. Internal contamination occurs when radioactive materials are ingested, inhaled, or absorbed through skin or wounds, or when neutron irradiation occurs. If radioactive atoms enter cells, they are said to be “incorporated.” As long as radioactive materials are on or in a person, the person is being irradiated. Contamination does not cause symptoms, unless the contaminants are corrosive, toxic, or thermally hot. However, note that fission product fallout (i.e., from a nuclear weapon or nuclear reactor core damage) should be brushed off the skin and clothing as soon as possible, since it can be highly radioactive. Caregivers should use strict isolation precautions (including wearing cap, mask, gown, shoe covers, and double gloves) when handling contaminated victims, and gloves should be changed frequently to avoid cross contamination.

In most cases, external contamination can be readily detected with survey instruments and readily removed. Decontamination (removal of contaminants) can be accomplished by removal of the victim's clothing and thorough, careful washing with warm water and soap, followed by a radiation survey to determine if the washing procedure was sufficiently effective. *Except for victims of serious trauma, decontamination can be accomplished prior to admission to hospital emergency care. Uninjured individuals do not require hospitalization unless they are vomiting, have diarrhea, or have conventional reasons for seeking emergency care.*

Detection of internal contamination is accomplished by whole body counting and/or with excreta analysis. Internal contamination does not cause early signs or symptoms. During the first 24 hours, those who are not injured (but are suspected of being internally contaminated) should be advised to seek assistance from public health authorities. Public health authorities may recommend excreta collection and/or lung or whole body counts. If the radioactive contaminants have been identified, appropriate treatment will be instituted. For example, in the event of releases of radioactive iodines, public health officials would recommend administration of potassium iodide, especially to children and pregnant women.

Total body, partial body, or localized radiation injury can occur with external or internal contamination (see Table 3). Any of these radiation injuries can be complicated by the coincidental presence of trauma, chemical or thermal injury, as well as by serious pre-existing conditions (such as infections, uncontrolled diabetes, immune deficiencies, etc.).

Combined Injury: Combined injury is present when trauma, thermal, or chemical injury occurs along with a radiation exposure sufficient to cause immunosuppression, delayed healing, pancytopenia, and other problems. Combined injury is not likely with use of an explosive device such as a "dirty bomb," unless victims are trapped near sources of penetrating radiation. An overwhelming number of combined injury victims (and deaths) would be likely with a nuclear weapon detonation. Morbidity and mortality from thermal injury combined with the radiation injury would likely be high. *Victims with serious trauma, thermal or chemical injury require prompt assessment, stabilization, and subsequent treatment to conserve life and limb. Radiation exposure increases the probability of mortality when combined with other injuries or pre-existing conditions that result in immunosuppression, blood loss, and danger of infectious complications. Early management of trauma and early recognition and assessment of radiation injury are essential if lives are to be saved.*

Guidelines

The following guidelines are for dealing with an influx of victims of a nuclear or radiological catastrophe. They provide a fast, logical, and useful mechanism for gathering information and determining appropriate disposition of these patients. Figure 1 is an example of a form that can be used to document important patient information.

The guidelines are not intended to serve as a hospital's disaster plan. Ideally, such a plan should include a designated, prearranged triage area, and arrangements for the walking wounded, the worried well, concerned family members, etc. The guidelines could be useful for any hospital, clinic, or emergency care center receiving victims in the first 24 hours following a nuclear event.

The hospital staff should not hesitate to admit victims because of fear of radiation or because of concern about contamination. Contaminants can be readily located with radiation detection devices, and facility decontamination can be accomplished once an emergency is over. It is important to note that the United States has a large number of health physicists, medical physicists, radiation technicians, and others who are skilled in radiation detection, measurement, contamination control, and decontamination of personnel and facilities.

Initial Actions

(Hospital authority, emergency department supervisor, and/or emergency physician, according to existing hospital disaster plan.)

1. Gather information from the field.
 - 1.1 Assign a non-medical person the responsibility of gathering incident information and keeping track of updates.
 - 1.2 Request that a written log be kept of this information, including who provided the information, where they are, and how they can be contacted.
 - 1.3 Have this person contact fire, police, and EMS to remind them to remove victims' clothes and leave them at the scene, if possible.
2. Prepare for reception of victims.
 - 2.1 Initiate hospital disaster plan.
 - 2.2 Mobilize hospital radiation experts (i.e., radiation safety officer, nuclear medicine and radiation oncology specialists and all nuclear medicine and radiation oncology staff, as well as any radiologists not needed for trauma diagnostic studies). Request radiation monitoring and survey instruments. Request dosimeters for staff.
 - 2.3 Request extra security for the emergency department. *Be aware that a terrorist could be among the victims.* Request police assistance for traffic and crowd control, assistance with gathering evidence, etc.
 - 2.4 Identify areas on the hospital grounds for incoming 1) "walking wounded" victims and 2) "worried well" individuals. Assign security and appropriate staff to areas.
 - 2.5 Prepare the ED:
 - Identify the area where contamination will be tolerated. Use ropes, tape, signs or other means to designate "clean" or "dirty" areas. Establish control lines.
 - Request MANY large plastic bags and extra containers for waste, MANY boxes of plastic gloves, and necessary medical supplies.
 - 2.6 Prepare the staff. Staff should wear a scrub suit covered with a water resistant gown, or a Tyvek® suit or other clothing to keep contaminants off skin. They should also wear a cap, face mask, boots or shoe covers. Two pairs of plastic gloves should be worn at all times. The first pair of gloves should be taped to the gown or Tyvek® suit. The second pair of gloves should be changed after handling contaminated items and between patients. Dosimeters, if available, should be worn at the collar, but under protective clothing.
3. Go to page 6 for victims with no trauma. Go to page 14 for victims with trauma.

Guide for First 24 Hours in a Mass Casualty Situation

POSSIBLY IRRADIATED VICTIMS:

NO TRAUMA:

GUIDE

RATIONALE

1. Focused history of exposure
 - 1.1 Ask and record:
 - 1.1.1 Where were you when the incident happened? (Specific address/location)
 - 1.1.2 Were you inside a building/house?
 - 1.1.3 About how long were you outside?
 - 1.1.4 Have you vomited or had diarrhea? About what time did it start?
 - 1.1.5 How much do you weigh?
 - 1.2 Document if the person was decontaminated prior to admission.
 - 1.3 Document if a brief period of unconsciousness was reported.

Information about shielding and proximity of the victim to the source aids in determining the likelihood of radiation exposure. Subsequently, the information will be useful in dosimetry.

Vomiting and diarrhea are symptoms of radiation injury. The time to onset of vomiting is roughly correlated to dose (see 2.2 and Table 4).

Note that periodic measurements of patient's weight can guide fluid replacement for individuals with vomiting and diarrhea, since an overwhelmed professional staff will be unable to keep careful track of output. This is especially important for infants, children, the elderly and pregnant females.

Patients who are incapacitated because of vomiting, diarrhea or shock might be contaminated on arrival at the hospital. Removal of clothing and decontamination should be accomplished at the earliest opportunity.

GUIDE

2. Focused physical exam
 - 2.1 Take vital signs, including temperature. Repeat every 2 hours for symptomatic patients.
 - 2.2 Note especially the occurrence of vomiting and diarrhea. Document the severity and timing.
 - 2.3 Note and record erythema of skin and/or mucosa, nausea, parotitis, headache, unusual fatigue, abdominal cramps.
 - 2.4 Note and record a history and/or evidence of altered CNS function. Rule out trauma as a cause.
3. Laboratory tests
 - 3.1 Obtain baseline CBC with differential and absolute lymphocyte count (i.e. total white count times the percent of lymphocytes on the differential).

RATIONALE

Baseline measurements are important, since elevated temperature is related to dose, and development of hypotension is possible with high levels of exposure. (Rule out other causes.)

Less than 10% of persons vomit if the radiation dose is less than 1 Gray, whereas most vomit if the dose is more than 2 Gray. The time of vomiting is roughly correlated to dose (see Table 4).

The acute onset of diarrhea is associated with doses greater than 9 Gray. Abdominal cramps and strong bowel contractions could also be present.^{2,3}

Some symptoms of the acute radiation syndrome (such as fatigue, weakness, anorexia, headache) could be due to the physical and emotional stress of the situation or other causes. Vomiting and diarrhea can also be due to stress, but if present, radiation injury must be assumed until proven otherwise.

If there is a history of loss of consciousness or evidence of cerebral edema or other CNS abnormality not due to physical trauma or stress, with a history of early vomiting (within minutes) and diarrhea, the victim's dose is likely greater than 15 Gray. Long term survival is unlikely, since multi-organ failure will ensue.

Radiation exposure will cause early changes in blood cell counts.

Note: If the initial lymphocyte count is below 1000/microliter, suspect significant radiation exposure.

GUIDE

- 3.2 If vomiting and diarrhea occurred in the first 2 to 3 hours, consider the need for blood typing, HLA-sub-typing, and cytogenetic dosimetry. Obtain samples of blood before the lymphocyte count falls. Draw blood in heparinized tubes. If necessary, save for later analysis. Refrigerate but do not freeze.
 - 3.3 If history indicates that inhalation of radioactive materials was possible, ask patient (or parent of child) to collect a 24 hour urine specimen. (Any sealed container, properly labeled, is adequate. Refrigeration of the urine is not necessary.) Collection of stools might be necessary in some cases, but public health or radiation experts will advise regarding this.
 - 3.4 Request serum amylase (if situation allows it and depending on laboratory capabilities).
4. Initial treatment
 - 4.1 Anti-emetics, as needed. Ondansetron, granisetron, or other 5HT3 receptor antagonist.
 - 4.2 Anti-diarrheals: Loperamide hydrochloride, Lonox (diphenoxylate/atropine).
 - 4.3 Replace fluids and electrolytes as necessary.
 5. Follow-up labs
 - 5.1 Repeat CBC with differential and absolute count at 6, 12, and 24 hours.

RATIONALE

- Bone marrow, cord blood or peripheral blood stem cells might be needed in treatment of patients at risk for pancytopenia.
- Cytogenetic dosimetry provides the most reliable whole body dose measurement.
- Excreta analysis is useful in determining if radioactive materials have been inhaled or ingested.
- Some elements are poorly absorbed in the GI tract and are excreted in the feces. Others “recycle” through the GI tract and their presence in the body can be detected through measurements of the elements in the feces.
- Initial results provide a baseline. Greater than 0.5 Gray (50 rads) to the total body or parotid glands causes a significant rise in serum amylase. (Note: repeat measurement in approximately 24 hours.)

GUIDE

5.2 Review hematology lab results.

5.2.1 Absolute lymphocyte count.

5.2.2 Neutrophil count.

5.3 At 24 hours repeat serum amylase.

5.3.1 Review results in relation to baseline measurement.

5.4 Request serum electrolytes as necessary.

6. Follow-up physical exam at 6 and 12 hours

6.1 Did the body temperature change in the first 5 to 6 hours after the incident?

RATIONALE

Lymphocytes are extremely sensitive to ionizing radiation. A drop in the absolute lymphocyte count indicates radiation exposure.^{4,5} See Table 5: procedures for estimating dose, or refer to Figure 2 (Andrew's nomogram) for general severity estimates.

A temporary rise in neutrophils with a decreased absolute lymphocyte count occurs with serious radiation exposures.

Greater than 0.5 Gray (50 rads) to the whole body or parotid gland areas cause a significant rise in serum amylase. The rise reaches a maximum between 4 and 10 Gray, but the level is not well correlated with dose.⁶

Elevated temperature up to 5 hours after a radiation exposure is related to a dose greater than 2.5 Gray. The sooner the temperature rises, the higher the radiation dose.^{2,3,7}

GUIDE

6.2 Note and record location of any erythema of skin and/or mucosa.

6.3 Ask, observe, and record continuing or developing symptoms of the acute radiation syndrome: unusual fatigue, anorexia, nausea, vomiting and diarrhea (record frequency, timing, and severity), headache, muscle weakness, altered reflexes, abdominal cramps, parotitis, hypoxemia, hypotension. Observe for evidence of dehydration.

RATIONALE

Note that erythema can disappear from one area and reappear in another area. Early (occurring in less than 6 hours after exposure), widespread erythema could be a sign of a whole body dose of greater than 4 Gray and a skin dose much higher. Persons with extensive erythema will require care in a burn center or in a specialized facility. Documentation of areas of erythema will aid in determining the uniformity of the exposure, the general direction of gamma radiation and areas with highest levels of beta exposure. Erythema of mucosa portends development of radiation mucositis

Considerations for Patient Disposition:

Note: Disposition of patients might take place before laboratory test results are available. If a patient is transferred to another facility, the receiving hospital should complete the test sequence and, as soon as feasible, contact the original hospital for transfer of initial test results. Test results will provide valuable information that will be useful in determining the subsequent medical treatment.

SIGNS AND SYMPTOMS

Vomiting a few minutes after exposure, diarrhea in less than an hour, fever in less than an hour, severe headache, possible history of a period of unconsciousness or altered consciousness, possible hypotension, abdominal cramps, erythema, parotid pain.

Onset of vomiting less than 30 minutes after exposure incident, early fever, severe headache, possible diarrhea within 2 hours, parotid pain, possible erythema. Prodromal symptoms are severe.

DECISION AND FOLLOW-UP

Supportive/palliative care is needed. Draw blood for CBC and differential and cytogenetic dosimetry. Evaluate daily CBC and re-evaluate as more information is available. (Note: *If resources are NOT scarce, treat as following group.*) Prolonged survival is possible with intensive medical care, but prognosis is poor.

Intensive care needed beginning day 1. If transfer is necessary because of the number of patients or because other expertise is needed, transfer on day 1 or as soon as feasible. The latent period of the acute radiation syndrome (ARS) might be short or absent with higher doses, with the prodromal period followed by a continuing severe illness.

Cytogenetic dosimetry is recommended. Blood and tissue typing are needed. Hematopoietic growth factor therapy should begin early. Viral prophylaxis recommended. CBC daily. Consult with hematologist. Consider cord blood transplant for children and peripheral blood stem cell transplant for adults.

SIGNS AND SYMPTOMS

Onset of vomiting in less than 1 hour of incident, fever in 1 to 2 hours, diarrhea in 3 to 8 hours in less than 10% of victims. Parotid pain and erythema possible in some patients.

Nausea, vomiting with onset 1 to 2 hours after exposure.

DECISION AND FOLLOW-UP

Hospitalization necessary. Prodrome lasts approximately 48 hours. Latent period follows, lasting 1 to 3 weeks. Intensive care might be needed during period of severe illness. Patient can be transferred to another hospital for intensive care if necessary.

CBCs with differentials daily. Cytogenetic dosimetry needed. Blood and tissue typing recommended. Viral prophylaxis recommended. Hematopoietic growth factor therapy needed. Consult with hematologist or radiation oncologist regarding use. Consider consult with pediatric hematologist regarding cord blood transplant for children. Peripheral blood stem cell transplant might be indicated for some victims.

Hospitalization or careful medical observation recommended. If hospital beds are scarce, hospitalization can be delayed unless patient is symptomatic. Patients can be transferred to other facilities if hospitalization is needed because of age, pre-existing medical condition, or other problem.

Prodrome lasts approximately 48 hours. A latent period follows, lasting 1 to 3 weeks. CBCs with differentials should be scheduled every 3 days or as necessary. Expect neutrophil and platelet count to reach nadir in 2 to 3 weeks. Cytogenetic dosimetry is recommended but not urgent. Some patients might need growth factors.

SIGNS AND SYMPTOMS

Anorexia, nausea, no vomiting more than 2 hours after irradiation.

DISCUSSION AND FOLLOW-UP

Provide instructions if hospitalization is delayed: make every attempt to avoid infections or injury; take temperature every day and notify physician of elevation; report for CBCs as requested; notify physician and report for hospitalization if fever, infection, bleeding from body orifice or injury occurs.

Collect blood for CBC and differential. *Discharge with instructions to return for CBC and differential in 1 week or earlier if problems arise. Out-patient follow-up is recommended.*

GUIDELINES: FIRST 24 HOURS IN A MASS CASUALTY SITUATION

INJURED VICTIMS, POSSIBLY IRRADIATED :

GUIDE

1. Attend to ABCs and standard trauma resuscitation.
2. Determine YES/NO if contaminated with radioactive material. (If personnel and survey instruments are not available, assume contamination.)
 - 2.1 Remove clothing if not accomplished previously.
 - 2.2 Delay further decontamination until patient is stable. However, if visible pieces of metal are embedded in tissue, assume they are radioactive and promptly use long forceps to remove the metal particles. Store them in a labeled container in a shielded area away from people.
3. Obtain abbreviated medical and exposure history (from rescuer or patient).
 - 3.1 Mechanism of injury, allergies, medications in use, etc.
 - 3.2 Focused history of exposure.
 - 3.2.1 Where was patient located at time of event (address, inside or outside, proximity to source if known, approximate time trapped in radiation area).
 - 3.2.2 Note report of or evidence of vomiting or diarrhea.

RATIONALE

- Radiation does not cause immediate life-threatening problems. Serious injury takes priority over concerns about contamination.
- Note that most contamination is removed with clothing.
- Quick action will reduce exposure to staff and patient.
- Distance and shielding will reduce exposure to staff and patient.
- Routine.
- Information about shielding and proximity of the victim to the source of radiation aids in estimating the likelihood of radiation exposure. Subsequently the information will be useful in dosimetry estimates.
- Vomiting and diarrhea are symptoms of acute radiation injury. The time of onset of GI symptoms is roughly correlated to

GUIDE

- 3.2.3 If patient is able to respond, ask weight.
- 4. Physical exam: routine, plus:
 - 4.1 Note and document vital signs and temperature every 2 hours or as necessary.
 - 4.2 Note and document erythema (noting areas and distinguishing between flame/flash burns and erythema due to radiation).
 - 4.3 Record frequency and timing of vomiting and diarrhea.
 - 4.4 Record presence of parotitis or parotid edema.
 - 4.5 Evaluate CNS symptoms. Rule out trauma as cause of symptoms.
- 5. Labs
 - 5.1 Obtain CBC, differential and absolute lymphocyte count.
 - 5.2 Request serum amylase.
 - 5.3 Type and cross-match prn. *If blood transfusion is needed, use irradiated blood if available.*
 - 5.4 Routine labs (as necessary for patient's condition).

RATIONALE

dose. (See Table 4.)

Hypoxemia and hypotension have occurred in victims after very high radiation doses. Elevated temperature in the first 5 to 6 hours occurs with a radiation dose greater than 2.5 Gray.

Flame and flash burns are painful and there is loss of hair in the involved area along with tissue loss (depending on the depth of the burns). The primary erythema caused by radiation is not accompanied by obvious loss of tissue and there is no hair loss. (Epilation does not occur for 2 to 3 weeks after an exposure.) Although the irradiated tissue might be somewhat edematous and feel "stretched" or "itchy," it is not painful.

Cells of the parotid are sensitive to radiation exposure. The presence of parotitis is an indication of radiation exposure.

Irradiation of blood prevents the transfusion of live WBC and reduces the chance of subsequent graft versus host disease.⁸

GUIDE

- 5.5 If patient has signs and symptoms of the ARS, consider the need for tissue typing and cytogenetic dosimetry. (Obtain samples early, before the lymphocyte count falls.)
- 5.6 Begin 24 hour urine collection.

6. Treat serious injuries according to usual protocols.
 - 6.1 Open wounds are considered to be contaminated, even if there is no visible material in the wound. Clean the area around the wound and drape. Flush wounds copiously using standard wound management. Debride as necessary. Close open wounds, or use biological wound dressings.
 - 6.2 If surgery is needed and there are indications of acute radiation syndrome, *necessary surgery should be completed* as soon as possible – *within the first 48 to 72 hours of the radiation injury*.

7. Plan to avoid additional surgery until hematopoiesis is restored.

8. Follow procedure for ARS. Note that lymphocyte dosimetry *may* be less reliable because of the physiologic response to trauma and thermal injury, as well as hemoconcentration or hemodilution associated with injury or therapy, use of transfusions, etc.

RATIONALE

Peripheral blood stem cell transplants (or cord blood for children), platelet, or RBC transfusions might be needed.

Excreta analysis is useful in determining if radioactive materials have been inhaled or ingested.

Wounds that are closed are less likely to allow entrance of infectious agents.

These patients will become leukopenic, thrombocytopenic, immunosuppressed, and anemic. Expect nadir at approximately 2 to 3 weeks, although it could occur sooner if significant blood loss occurred. (Note that the severity is dependent on the radiation dose.) These patients are at risk for prolonged healing times, delayed callous formation in fractures, and other complications.

Serious trauma or other stress can cause an initial lymphocytosis which is followed in a short time (hours) by lymphopenia. Other signs and symptoms indicating exposure (vomiting, diarrhea, erythema, and elevated temperature) might still be

GUIDE

RATIONALE

present, although vomiting is less reliable as an indicator of ARS if a patient is in pain, shock, or reacting to medication. Serum amylase (parotid) should not be affected by trauma unless parotids are involved

9. Considerations for patient disposition:
 - 9.1 Decisions to transfer for surgery, burn care or supportive care are based on the patient's injuries, clinical condition, age, the number of patients, etc. *Transfers should be carried out during the first 72 hours when possible. Necessary surgery should be completed within 72 hours.*
 - 9.2 Trauma or burn victims in serious or critical condition after initial stabilization, who have also been determined to be significantly irradiated (based on accident history, history of early vomiting, diarrhea, early elevated temperature, erythema, elevated serum amylase in first 24 hours) should be given palliative/compassionate care.
 - 9.3 Patients with radiation injury and trauma or thermal injury (greater than 10% BSA) should be *hospitalized or under watchful medical surveillance* because of the risk of immunosuppression and pancytopenia. Reverse isolation is recommended. If neutrophil or platelet counts are low, if infection, pre-existing illness, or other complicating factors are present, hospital care is recommended.
 - 9.4 Victims with simple fractures, after stabilization and decontamination, should be triaged according to ARS guide. Expect delayed callous formation.
 - 9.5 Victims with minor injuries will most likely have to wait for treatment. They should be showered and have clean clothing prior to hospital admission, if possible. Superficial skin wounds should be thoroughly washed while showering. After the wound is treated and covered, the patient should be triaged according to the ARS guide.
 - 9.6 Information or experience regarding combined injury in infants, young children, or the elderly is not available.

- Summary: With few exceptions, radiation accidents over the past 60 years have generated small numbers of patients requiring emergency or intensive care. Notable exceptions are the Chernobyl accident (1986) and the Cs-137 accident in Goiania, Brazil (1987). However, with the real threat of nuclear/radiological terrorism, an emergency department staff may be overwhelmed by individuals requiring or seeking medical attention after a malevolent act. Leadership, command and control, security and communication capability will be essential. Emergency department personnel would find it challenging to triage, evaluate, and treat large numbers of irradiated/contaminated victims. Specific guidance and the associated rationale are presented and provide a stepwise approach to patient care.

This paper outlines the important questions to ask and procedures to follow for the first 24 hours of patient management in a mass casualty situation. Suggestions for patient transfer and disposition are also addressed.

Life threatening trauma should be dealt with promptly and injured managed according to usual accepted practice with some exceptions regarding timing of surgical intervention and wound closure. It is important to stress that good clinical medicine should be practiced in spite of the distractions of the situation and personal concerns about contamination and radiation exposure.

Table 1 Types of Nuclear/Radiological Catastrophes

1. Detonation of a “dirty bomb,” (an explosive device used to disperse radioactive material) or detonation of the high explosives in a nuclear weapon without a nuclear yield:

Problems:

- Explosive dispersal of radioactive material in the environment.
- Blast injuries, burns, and trauma, with possible entrapment of some victims.
- Possible localized radiation injuries due to radioactive material blown onto skin or embedded in wounds.
- Internal contamination of victims if material is vaporized or dispersed in ultra-fine particles.
- Acute radiation syndrome not likely unless victims are trapped near high activity sources emitting penetrating gamma radiation (such as Ir-192, Cs-137, Co-60).
- Widespread psychological trauma.
- Vaporization/aerosolization of radioactive materials and subsequent dispersal by wind and weather could cause contamination of the environment and economic disruption.

2. Explosive destruction of a nuclear reactor:

Problems:

- Blast injury to those in vicinity.
- Radiation exposure and contamination to those onsite and in surrounding areas.
- Widespread psychological trauma
- Airborne dispersal of radioactive materials which would cause contamination of the environment and economic depression.
- Release of radioactive iodine would necessitate administration of thyroid blocking potassium iodide (KI) to children, pregnant women, and others.

Note that implementation of existing and well rehearsed emergency response plans would substantially minimize the number of injuries caused by radiation.

3. Detonation of a nuclear weapon:

Problems:

- Massive widespread destruction with catastrophic consequences from blast, heat, and radiation.
- Hundreds to thousands of immediate deaths.
- Hundreds to hundreds of thousands of victims with burns, blast injuries and trauma, radiation exposure, contamination, flash blindness, etc.
- Destruction of medical facilities, fire, EMS services, and emergency management capabilities in the involved area, with loss of personnel.
- Widespread contamination of environment.
- Nationwide psychological trauma.
- Computer, electrical equipment, phone system, etc., malfunction due to an electromagnetic pulse that can occur with a nuclear detonation.

Table 2 Ways to Reduce Exposure from a Source of Radiation

<ul style="list-style-type: none"> • <u>Reduce time</u> near a radiation source to lower exposures. Work quickly and efficiently. • <u>Increase distance</u> from a radiation source to lower exposure. When not involved in care of a contaminated patient, remain a few feet away from the patient. Use long handled forceps to remove contaminated particles, dressings, etc. • <u>Shielding</u> (such as from buildings, walls or debris) lowers exposure. Put contaminated metal or glass in lead containers. Place bags of contaminated waste in secure concrete walled areas away from the immediate work area.

Table 3 Types of Radiation Injury

<p>Radiation injury can occur in any of the following ways:</p> <p>Total or partial body irradiation (exposure) can be present <u>with</u> or <u>without</u> any of the following:</p> <ul style="list-style-type: none"> • Internal and/or external contamination. • Trauma. • Local radiation injury. <p>Local radiation injury can be present with or without:</p> <ul style="list-style-type: none"> • Internal and/or external contamination. • Trauma. <p>External contamination can be present with or without:</p> <ul style="list-style-type: none"> • Internal contamination. • Trauma.
--

Table 4 Estimation of Dose Related to Onset of Vomiting

<p>For <i>single, acute exposure</i>, note time of onset of vomiting and estimated dose range. The timeframe for onset of symptoms varies if dose rate was low (i.e., total exposure was spread over time).</p>	
<p>Vomiting in ____ of incident:</p> <p>Less than 10 minutes</p> <p>10-30 minutes</p> <p>Less than 1 hour</p> <p>1-2 hours</p> <p>More than 2 hours after</p>	<p>Estimated dose:</p> <p>>8 Gy</p> <p>6-8 Gy</p> <p>4-6 Gy</p> <p>2-4 Gy</p> <p>Less than 2 Gy</p>

Adapted from IAEA Safety Report Series No. 2 Table VIII, p 16.²

Table 5 Procedure for Determining Approximate Dose Based on Lymphocyte Count

Determine initial lymphocyte count and subsequent counts at 6 or 12 hours. Divide initial count (L1) by (L2). Take natural log of quotient. Divide result by the time change in 24 hours (number of hours between counts divided by 24) to determine K. Refer to table below for estimated dose:

(K=)	(Est. dose in Gy:)	(99% confidence limits:)	(K=)	(Est. dose in Gy:)	(99% confidence limits:)
0.1	1.24 Gy	0.98-1.5 Gy	1.0	6.82	5.95-7.69
0.2	2.27	1.87-2.68	1.5	8.18	6.9-9.46
0.4	3.90	3.36-4.43	2.0	9.09	7.43-10.74
0.6	5.11	4.5-5.73	2.5	9.73	7.76-11.71
0.8	6.06	5.33-6.79	3.0	10.22	7.98-12.45

Adapted from Goans RE, Holloway EC, Berger ME, Ricks RC. Early Dose Assessment Following Severe Radiation Accidents. Health Physics, 1997, 72(4), 513-18.⁴

Figure 1

Name _____ Date _____ Time _____ am/pm M F Age _____

DOB _____ Weight _____ Allergies y/n _____

Medications in use _____

Location/address at time of incident _____ Inside/Outside?

S and S	Onset time (am/pm)	VS time									Use body diagram to locate injuries and areas of erythema.
<input type="checkbox"/> Nausea		BP									
<input type="checkbox"/> Vomiting		P									
<input type="checkbox"/> Diarrhea		R									
<input type="checkbox"/> Headache		Temp									
<input type="checkbox"/> Parotitis		LOC									
<input type="checkbox"/> Erythema											

INJURIES: _____

PATIENT CARE AT THIS HOSPITAL:

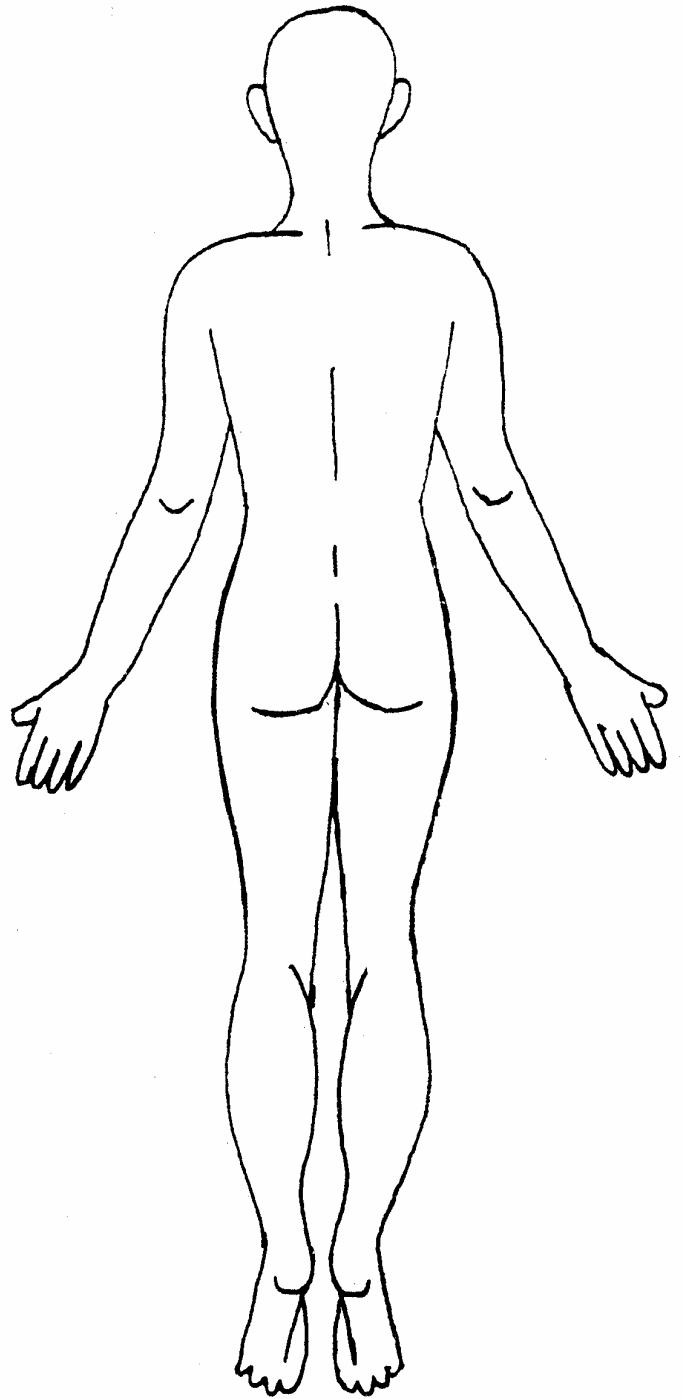
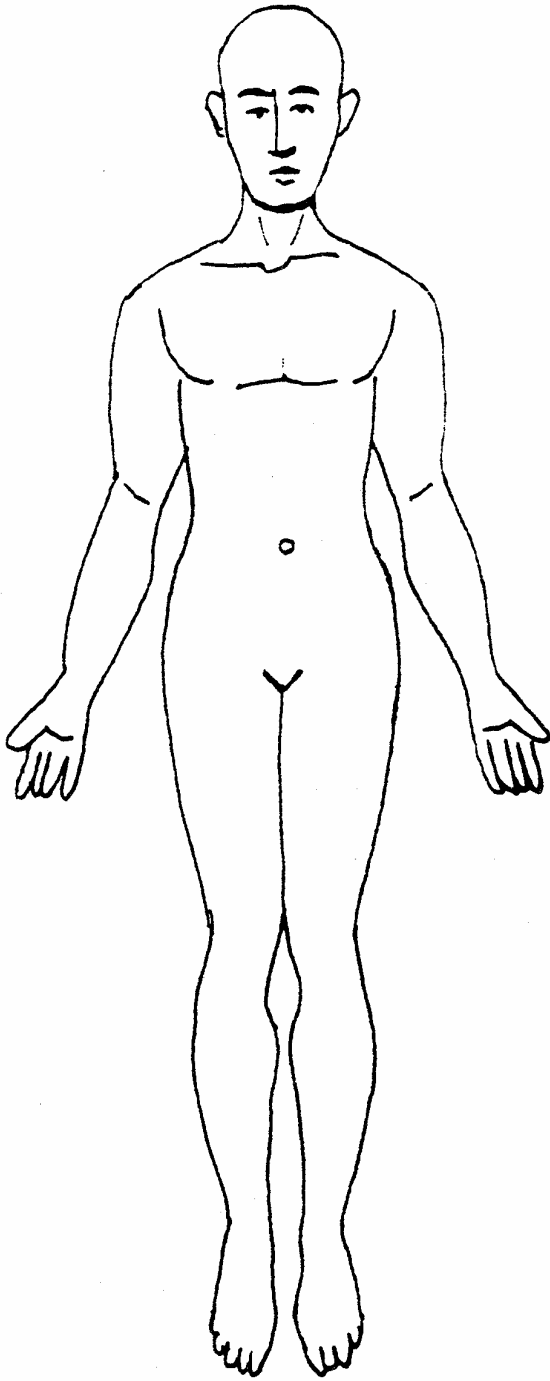
Medications:	Time						

Labs Ordered:	Results: (Attach results if possible)

Therapy/Surgery/Notes (Use back for additional information):

Signature: _____

Identify Areas of Injury, Erythema

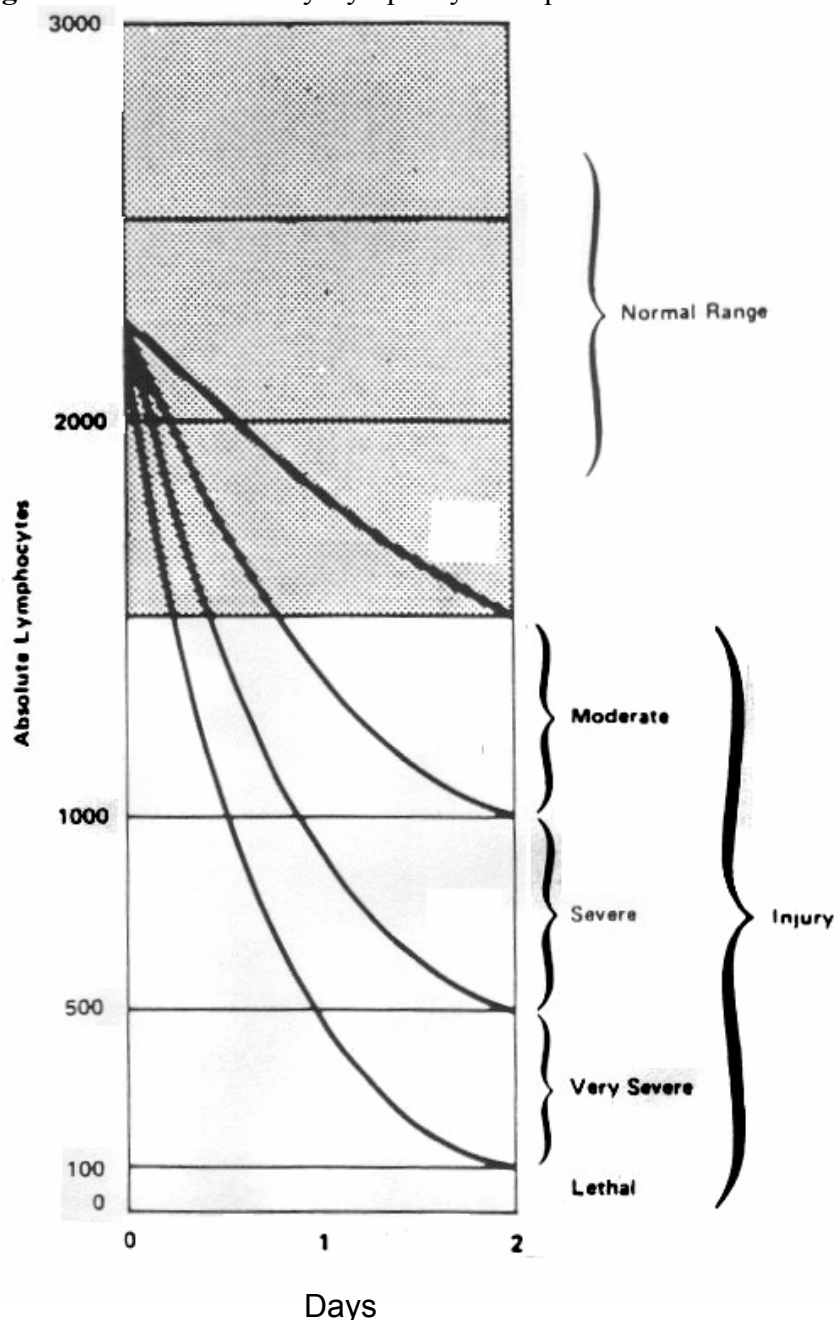


Name _____

M F Date of Birth _____

Date _____ Time _____

Figure 2 Patterns of Early Lymphocyte Response in Relation to Severity of Injury.



From Andrews G. Medical Management of Accidental Total Body Irradiation. In: The Medical Basis for Radiation Accident Preparedness. KF Hubner, SF Fry, eds. Elsevier North Holland Inc. 1980, 297-310.⁵

References:

1. Lushbaugh, CC. The Impact of Estimates of Human Radiation Tolerance upon Radiation Emergency Management; in the Control of Exposure of the Public to Ionizing Radiation in the Event of Accident or Attack. NCRP. Bethesda, MD, 1982; 46-57.
2. International Atomic Energy Agency. Diagnosis and Treatment of Radiation Injuries. Safety Report Series No. 2. Vienna, 1998.
3. Hartmann, A, Bojar, H, Zamboglou, N, et al. The Significance of Clinical Prodromes for Dosage Estimation after Whole Body Radiation Exposure. *Strahlenther Onkol*, Sept.1994; 170(9): 538-544.
4. Goans, RE, Holloway, EC, Berger, ME, Ricks, RC. Early Dose Assessment Following Severe Radiation Accidents. *Health Physics*, 1997, 72(4) 513-18.
5. Andrews, G. Medical management of accidental total-body irradiation. In the *Medical Basis for Radiation Accident Preparedness*. KF Hubner, SA Fry editors. Elsevier North Holland, Inc., 1980; 297-310.
6. Dubray, B, Girinski, T, Thames, HD, et al. Post Irradiation Hyperamylasemia as a Biological Dosimeter. *Radiother Oncol*, May 1992, 24(1): 21-26.
7. Chaillet, MP, Cosset, JM, Socie, G, et.al. Prospective study of the clinical symptoms of therapeutic whole body irradiation. *Health Physics*, April 1993, 64(4) 370-74.
8. Hirsch, EF. The Status of Combined Injuries in Treatment of Radiation Injuries. Brown D, Weiss SF, MacVittae TJ, and Pillai M, editors. Plenum Press; NY 1990; 141-144.

Additional Resources:

1. American Medical Association. A Guide to the Hospital Management of Injuries Arising from Exposure to or Involving Ionizing Radiation. Chicago, IL, Jan. 1984.
2. Anno, GH, Baum, SJ, Withers, HR, Young, RW. Symptomatology of Acute Radiation Effects in Humans and Exposure to Doses of 0.5-30 Gy. *Health Physics* 72(4) 513-18, 1997.
3. Berger, ME, Ricks, RC. Management of emergency care for radiation accident victims. In *CRC Handbook of Management of Radiation Protection Programs*, 2nd Edition. KL Miller ed. CRC Press 1992; 105-115.
4. Cosset, JM, Girinsky, Y, Helfre, S, Gourmelon, P. Medical management during the prodromal and latent periods. In the *Medical Basis for Radiation Accident Preparedness: Clinical Care of Victims*. RC Ricks, ME Berger, FM O'Hara editors. Parthenon Publishing Company, 2002, 45-51.
5. Dainiak N. Hematologic consequences of exposure to ionizing radiation. *Exp. Hematol* 2002 JUN;30(6):513-28.
6. Defense Nuclear Agency. Consensus summary statement on the treatment of radiation injuries. In *The Treatment of Radiation Injuries*. Browne, D, Weiss, JF, MacVittie, TJ, Pillai MV eds. Plenum Press, NY, 1990.
7. Goans, RE. Clinical care of the radiation accident patient: patient presentation, assessment, and initial diagnosis. In the *Medical Basis for Radiation Accident Preparedness: Clinical Care of Victims*. RC Ricks, ME Berger, FM O'Hara editors. Parthenon Publishing Company, 2002, 11-22.
8. Hogan DE, Kellison T. Nuclear terrorism. *Amer J Med Sci*. 2002 June 323(6):341-9.

9. Leonard, RB, Ricks, RC. Hospital Emergency Department Radiation Accident Protocol. *Annals of Emergency Medicine*. 9:9 (Sept.), 1980;462-70.
10. Levi, MA, Kelly, HC. Weapons of Mass Disruption. *Scientific American*, Nov. 2002; Vol 287, No. 5:76-79.
11. Mettler, FA, Ricks, RC. Medical Management of Radiation Accidents. *Contemporary Diagnostic Radiology*, 1982, Vol. 5, No: 8; 1-6.
12. Mettler FA, Voelz GL. Major radiation exposure – what to expect and how to respond. *N Engl J Med*, Vol 346, no. 20. May 16, 2002. 1554-61.
13. Micromedex Web site: www.micromedex.com.
14. REAC/TS Web site: www.ornl.gov/reacts.
15. Ricks, RC, Hospital Emergency Department Management of Radiation Accidents. ORAU, Oak Ridge, TN, 1984.

The **Oak Ridge Institute for Science and Education (ORISE)** is a U.S. Department of Energy facility focusing on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists. ORISE is managed by Oak Ridge Associated Universities.

The material was prepared as an account of work sponsored by the United States Government. Neither ORAU nor the United States Government, nor the U.S. DOE, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe on privately owned rights. The views and opinions of authors expressed herein do not necessarily state or reflect those of the U.S. Government or any agency thereof.

Acknowledgement

The authors would like to gratefully acknowledge the assistance of Pat Cooley, Administrative Manager of REAC/TS in preparation of this manuscript.

Authors

ME Berger, RN, EdD – Retired. Formerly Associate Director, Radiation Emergency Assistance Center/Training Site (REAC/TS)

RB Leonard, PhD, MD, FACEP – Wake Forest University School of Medicine

RC Ricks, PhD – Director, Radiation Emergency Assistance Center/Training Site (REAC/TS)

AL Wiley, MD, PhD, FACR, FACNM – Radiation Emergency Assistance Center/Training Site (REAC/TS)

PC Lowry, MD, MPH – Medical Section Leader, Radiation Emergency Assistance Center/Training Site (REAC/TS)

DF Flynn, MD – Holy Family Hospital and Medical Center; Harvard Medical School