Disaster Preparedness for Radiology Professionals

Response to Radiological Terrorism

A Primer for Radiologists, Radiation Oncologists and Medical Physicists

American College of Radiology
www.acr.org

Preface

The American College of Radiology (ACR) Disaster Planning Task Force, in collaboration with the American Society for Therapeutic Radiology and Oncology (ASTRO) and the American Association of Physicists in Medicine (AAPM), offers this primer as part of an educational program to enable the radiology community to respond effectively to a terrorist attack. As we learned on Sept. 11, 2001, a large-scale disaster can strike without warning. The attacks on the World Trade Center and the Pentagon and several incidents of anthrax in the mail placed our colleagues on the front lines in New York, Washington, D.C. and other venues, triaging the injured and diagnosing those infected with biological agents. Government officials have issued warnings about the possible use of radiological and chemical weapons in future attacks.

A radiation disaster is a possibility for which we must be prepared. Radiologists, radiation oncologists and medical physicists will play a vital role as responders and as sources of accurate information for patients, the public and the medical community.

This primer is not intended to serve as a comprehensive treatment guide, but rather as a quick reference in the event of a radiation disaster. It summarizes current information on preparing for a radiation emergency, handling contaminated persons, dose assessment and radiation exposure health effects. It also includes information on radiological findings related to agents of biological and chemical terrorism because radiologists may be involved in the diagnosis of conditions associated with such exposures. Readers are encouraged to utilize the references listed at the end to develop more in-depth knowledge.

The College will continue to expand its educational resources for disaster preparedness and will provide updates as new materials are added. Please check the ACR Web site regularly for information and updates (www.acr.org).

Members of the ACR Disaster Planning Task Force

Arl Van Moore, MD, FACR, *Chair*
Secretary/Treasurer, ACR Board of Chancellors
President, Charlotte Radiology

E. Stephen Amis Jr., MD, FACR
Vice Chair, ACR Board of Chancellors
Professor/Chair, Department of Radiology, Montefiore Medical Center

Harris L. Cohen, MD, FACR
Professor of Radiology, SUNY-Stony Brook
Visiting Professor of Radiology, The Russell H. Morgan Department of Radiology and Radiologic Science, Johns Hopkins Medical Institutions

John D. Earle, MD
Chair, Joint ACR/ASTRO Committee on Government and Public Relations
Professor/Chair, Department of Radiation Oncology, Mayo Clinic Jacksonville

Douglas W. Fellows, MD
Colonel, United States Army
Radiology Consultant to The Surgeon General, United States Army
Chief, Department of Radiology, Keller Army Community Hospital

Roger E. Linnemann, MD
President, Radiation Management Consultants

Richard L. Morin, PhD, FACR
Chair, ACR Commission on Medical Physics
Brooks-Hollern Professor, Mayo Clinic Jacksonville

Harvey L. Neiman, MD, FACR
Chair, ACR Board of Chancellors
Chair, Department of Radiology, The Western Pennsylvania Hospital
Clinical Professor, Diagnostic Radiology, University of Pittsburgh, School of Medicine

Arlene H. Olkin, MA, *Staff liaison*
ACR Senior Director, Education

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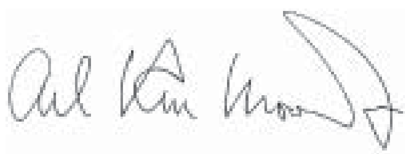

Arl Van Moore, Jr., MD, FACR
Chair, Disaster Planning Task Force

Preparing for radiological terrorism means planning in advance so as to act appropriately.

In the event of a terrorist disaster, you and your facility will be required to carry out these "10 basics of response."

1. Assure medical staff that when an incident combines radiation exposure with physical injury, initial actions must focus on treating the injuries and stabilizing the patient. *See Sections VI and VII*.

2. You or your hospital must be prepared to manage large numbers of frightened, concerned people who may overwhelm your treatment facility. *See Section VII*.

3. You or your hospital must have a plan for distinguishing between patients needing hospital care and those who can go to an off-site facility. *See Sections VII and VIII*.

4. You or your hospital must know how to set up an area for treating radiation incident victims in an ER. *See Section V and Appendix C*.

5. You or your hospital should be aware that a good way to approach decontaminating a radioactively contaminated individual is to act as if he or she had been contaminated with raw sewage. *See Section X*.

6. You or your hospital must know how to avoid spreading radioactive contamination by using a double sheet and stretcher method for transporting contaminated patients from the ambulance to the emergency treatment area. *See Section V*.

7. You must know how to recognize and treat a patient who has been exposed to significant levels of radiation. *See Sections VIII, IX and X*.

8. You should recognize the radiological findings of illness/injury caused by biological or chemical terrorist agents. *See Table 8*.

9. You should know what agencies or organizations to contact in the event of a radiation emergency and how to reach them. *See Federal and State Emergency Contacts Section*.

10. You or your hospital must have a plan to evaluate and counsel non-injured patients exposed to radiation at a location outside of the hospital. *See Section VII*.

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Radiation Incidents

I. Radiation Threat Scenarios

Medical providers must be prepared to adequately treat injuries complicated by ionizing radiation exposure and radioactive contamination. Nuclear detonation and other high-dose radiation situations are the most critical (but less likely) events as they result in acute high-dose radiation. The following scenarios are adapted from *Medical Management of Radiological Casualties Handbook* (Jarrett, 1999).

Acute high-dose radiation occurs in three principal situations:

- A nuclear detonation which produces extremely high dose rates from radiation during the initial 60 seconds (prompt radiation) and then from the fission products in the fallout area near ground zero.
- A nuclear reaction which results if high-grade nuclear material were allowed to form a critical mass (“criticality”) and release large amounts of gamma and neutron radiation without a nuclear explosion.
- A radioactive release from a radiation dispersal device (RDD)* made from highly radioactive material such as cobalt-60 which can result in a dose sufficient to cause acute radiation injury.

II. Exploitable Sources of Radioactive Contamination

A terrorist could obtain radioactive material from one of several different sources. The following summary is adapted from US Army Center for Health Promotion and Preventive Medicine Technical Guide 238, Identification of Radiological Sources of Potential Exposure and/or Contamination (Falo, Reyes and Scott, 1999).

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* An RDD is any dispersal device causing purposeful dissemination of radioactive material across an area without a nuclear detonation. A terrorist or combatant with conventional weapons and access to radionuclides from sources such as a nuclear waste processor, nuclear power plant, university research facility, medical radiotherapy clinic or industrial complex can develop an RDD. This type of weapon causes conventional casualties to become contaminated with radionuclides and would complicate medical evacuation from the area. Damaged industrial radiography units and old reactor fuel rods can also cause significant local radiation hazards (Jarrett, 1999).

A. Radiation Sources and Contaminants Found in Nature

These sources form a part of our natural environment and their presence may be unavoidable. When they occur in large concentrations or have been concentrated for use, they may pose a threat to humans and appropriate precautions should be taken. [Examples of isotopes involved are ^{220}Rn and its daughters, ^{40}K, isotopes of uranium (^{234}U, ^{235}U, and ^{238}U), and ^{232}Th].

B. Radiation Sources Related to the Nuclear Fuel Cycle

This includes the six processes in the nuclear fuel cycle:

1. Mining and milling (^{235}U and its daughters, ^{238}U and its daughters, ^{222}Rn and its daughters)
2. Conversion (^{235}U and its daughters, ^{238}U and its daughters, ^{222}Rn and its daughters)
3. Enrichment (enriched ^{235}U product, depleted ^{238}U waste)
4. Fuel fabrication (^{235}U and its daughters, ^{238}U and its daughters, ^{222}Rn and its daughters, and isotopes of plutonium)
5. Products from reactor operations (same as above step plus fission products: Gases [^{3}H, isotopes of krypton, isotopes of xenon], Solids [^{88}Rb, isotopes of strontium, isotopes of iodine (including ^{131}I), isotopes of cesium] plus neutron activation products (in reactors components): ^{51}Cr, nitrogen, cobalt, and magnesium isotopes, ^{41}Ar)
6. Nuclear waste (^{235}U and its daughters, ^{238}U and its daughters, ^{222}Rn and its daughters, and isotopes of plutonium, most of above fission by-products with longer half-lives)

C. Radiation Sources Used in Medical Diagnosis and Therapy

These include primarily isotopes used in nuclear medicine diagnostic imaging and therapy (^{99}Tc, ^{123}I), isotopes used by oncologic radiology for therapy (^{60}Co, ^{137}Cs, ^{192}Ir, ^{131}I, ^{125}I, ^{226}Ra, ^{32}P, and ^{103}Pd) as well as radioisotopes used in biomedical research (^{125}I, ^{32}P, ^{3}H, ^{35}S, ^{14}C). All could be potential ingredients in a radiation dispersion weapon.

D. Radiation Sources Present in Military Equipment

Radioactive components are in Army commodities and weapons systems ^{3}H (in aiming components for M1 Series tanks, Howitzer artillery pieces, mortars, M16A1 rifles, and M11 pistols), ^{63}Ni (chemical agent monitor), ^{137}Cs (soil density testing), ^{147}Pm (M72 Light Anti-tank Weapon), ^{226}Ra (gauges and instrumentation), ^{232}Th (portable gas lanterns/ANVDR-2 and AN/VDR-77 radiac meters, Depleted Uranium (DU) (projectile rounds and weapon systems), and ^{241}Am (M43A1 Chemical Agent Detector/MC-1 Density and Moisture tester). Nuclear-powered submarines and aircraft carriers are also sources.

Other military commodities contain radioactive components, including:

^{3}H (watches, weapons sites, telescopes, pistols, rifles)

^{63}Ni (chemical agent monitor)

^{137}Cs (soil testing)

^{147}Pm (luminous paint)

^{226}Ra (older equipment gauges)

^{232}Th (radiac meter)

Depleted Uranium (Abrams tank, Marine Corps Harrier jet, Air Force A-10 aircraft, Bradley fighting vehicle)

^{241}Am (M43A1 Chemical Agent Detector)

E. Radiation Sources Used in Industry

Naturally Occurring Radioisotopes

^{3}H (studying sewage and ground water)

^{14}C (measuring age of water)

^{36}Cl (measuring sources of chloride and the age of water)

^{210}Pb (dating layers of soil and sand)

Artificially Produced Radioisotopes

^{46}Sc, ^{110}mAg, ^{60}Co, ^{140}La, ^{198}Au (Blast furnaces)

^{51}Cr, ^{198}Au, ^{192}Ir (studying coastal erosion)

^{54}Mn, ^{65}Zn (predicting behavior of heavy metal components in mining)

^{57}Co, ^{57}Fe (Soil analysis)

^{60}Co (food irradiation, industrial radiography, gamma sterilization)

^{82}Br (hydrological tracing)

^{85}Kr (reservoir engineering)

^{90}Sr, ^{144}Ce, ^{147}Pm (radiation gauges, automatic weighing equipment)

^{99m}Tc, ^{198}Au (tracing sewage and liquid waste movements)

^{137}Cs (industrial radiography, radiation gauges, automatic weighing equipment, food irradiators, tracing soil erosion and deposition)

^{169}Yb, ^{170}Tm, ^{192}Ir (industrial radiography)

^{239}Pu, ^{241}Am, ^{252}Cf (borehold logging)

^{241}Am (smoke detectors)

F. Radioactive Equipment and Materials Which May Require Transportation

X-ray machinery (radiography units, electron microscopes, spectroscopy equipment, diffractometer equipment)

Industrial accelerators

Packages containing radioactive materials, transported nuclear fuel and contaminated and spent fuel from nuclear power plants (*see section B*)

Radioactive waste (waste materials from industrial and biomedical practices-*see section C*)

III. Types of Radiation Incidents/Accidents

The following is adapted from a chapter in *Medical Management of Radiation Accidents, 2nd Edition* (Gusev et al, 2001, pp. 9-10).

Radiation accidents can arise from problems with nuclear reactors, industrial sources and medical sources. The existence of these accident potentials has been present for many years. Our society has developed safeguards to significantly reduce the likelihood of an accident to very low levels. Events of the past few years highlighted by the World Trade Center catastrophe place another risk on the table. That new risk is the intentional non-accidental radiation catastrophe produced by an act of terrorism.

Although there are some differences between various types of incident sources, there are elements common to all of them. Regardless of where the incident occurs, there are two general categories of radiation incidents: **external exposure**, which is irradiation from a source distant or in close proximity to the body; and **contamination**, defined as unwanted radioactive material in or on the body. The types may occur in combination.

Almost all industrial accidents, most reactor accidents and many medical accidents result in irradiation of the victim. There does not have to be direct contact between the victim and the radiation source, which may be a radiation-producing machine or a radioactive source. Once the person has been removed from the source of radiation, or the machine has been turned off, the irradiation ceases. The victim is not a secondary source of radiation and individuals providing support and treatment are in no danger of receiving radiation from the victim. A person exposed to external irradiation does not become radioactive and poses no hazard to nearby individuals.

External irradiation can be divided into **whole-body** exposures or **local** exposures. In either case, the effective dose can be calculated, as discussed below, taking into account the attenuation of the body and the steep gradients of absorbed dose throughout the body.

Contamination, the second category of exposure, results in an entirely different approach to the care and treatment of victims. Contamination may be in the form of radioactive gases, liquids or particles. Caregivers and support personnel must be careful not to spread the contamination to uncontaminated parts of the victim's body, themselves or the surrounding area. Internal contamination can result from inhalation, ingestion, direct absorption through the skin or penetration of radioactive materials through open wounds (Gusev et al, 2001).

To summarize (Table 1), radiation injuries result from either **External Exposure** or **Contamination**.

IV. Quantities and Units - Definitions

Exposure: A quantity used to indicate the amount of ionization in air produced by X- or gamma-ray radiation. The unit is the roentgen (R). For practical purposes, one roentgen is comparable to 1 rad or 1 rem for X and gamma radiation. The SI (Système International d'Unités, or international system of units) unit of exposure is the coulomb per kilogram (C/kg). One R = 2.58×10^{-4} C/kg. [REAC/TS Web site]

Available at: http://www.orau.gov/reacts/definitions.htm.

Table 1: Classification of Radiation Injuries

External Exposure:	Partial and Whole Body (TBI)*
Contamination:	External and Internal
Combined:	Exposed with contamination
	Above with trauma or illness

*TBI: Total Body Irradiation
(Linnemann, 2001)

Dose: A general term for the quantity of radiation or energy absorbed. The unit of dose is the gray (Gy). An older unit still used in the literature is the rad (radiation absorbed dose). 1 Gy = 100 rad

Dose Rate: The dose of radiation per unit of time.

Free-in-air Dose: The radiation measured in air at any one specific point in space. Free-in-air dose is very easy to measure with current field instruments, and more meaningful doses such as midline tissue dose or dose to the blood-forming organs, may be estimated by approximation. Military tactical dosimeters measure free-in-air doses (AFRRI, 1999).

Equivalent Dose: Different radiations have different biological effects as their energy is absorbed in tissue. For example, as a result of energy deposition differences, 1 Gy of alpha radiation produces much more severe reactions than 1 Gy of X or gamma radiation. This difference is adjusted by a quality factor (QF). The absorbed dose in rads times the QF yields the rem (radiation equivalent, man). The international unit for this radiation equivalency is the sievert (Sv) and is appropriately utilized when estimating long-term risk of radiation injury. Since the quality factor (QF) for X-ray or gamma radiation equals 1, then for pure gamma radiation:

100 rad = 100cGy = 1000mGy = 1Gy = 1 Sv = 100 rem (AFRRI, 1999)

An accident that results in a whole body exposure of 4 Sv is very serious, perhaps life-threatening. An accident resulting in a dose of 4 Sv only to the hand is serious, but not life-threatening.

Effective Dose: Effective dose (ED) is a quantity invented by the International Commission on Radiological Protection (ICRP). ED must be calculated. It cannot be measured. It is calculated by multiplying actual organ doses by *weighting factors* which indicate each organ's relative sensitivity to radiation, and adding up the total of all the numbers—the sum of the products is the *effective whole-body dose* or simply, *effective dose*. These weighting factors are designed so that the effective dose represents the dose that the total body could receive (uniformly) that would yield the same cancer risk as various organs getting different doses (Stabin, 2001).

The unit of ED is the sievert, with the older unit, the rem, still in use.

Principles of Dose Reduction: The three factors of radiation dose reduction are time, distance, and shielding. Reduction of radiation exposure comes about by reducing the time of exposure and increasing the distance of the exposed from the radiation source and the amount of shielding between the source and the individual (Gusev et al, 2001).

Recommendations regarding treatment of exposed patients can be found in Appendix A.

V. Hospital Response

A hospital should initiate its emergency radiological response upon notification of an incident **(see Appendix B, Radiation Accident Hospital Response)**. Designated personnel should immediately report to the individual in charge of the facility's radiation protection program. Ambulance personnel should be notified which entrance has been designated for receipt of radiological casualties for transport to the emergency room. Nonskid plastic sheeting can be placed as needed down the corridors where ambulance stretchers are wheeled to the ER. If injuries are not serious, the patient may be wrapped in clean sheets and transferred from the ambulance stretcher to a clean stretcher and then down the usual corridors with the contamination contained within the wrappings (NCRP, 2001).

By using a double sheet, contaminated clothing can be cut off and removed by rolling the patient from one side to the other to free the clothing. Clothing is wrapped in the inner sheet and removed to a plastic bag. The outer sheet remains around the patient (Gusev, 2001).

Recommendations for the floor plan of a radiation emergency area are contained in Appendix C. (For a detailed description, refer to Gusev, 2001, pp. 427-28.)

VI. Order of Management and Treatment of Radiological Casualties

1. Treat and stabilize life-threatening injuries
2. Prevent/minimize internal contamination
3. Assess external contamination and decontamination
4. Contain contamination to treatment area
5. Minimize external contamination to medical personnel
6. Assess internal contamination (concurrent with above)
7. Assess local radiation injuries/burns

8. Follow-up patients with significant whole-body irradiation or internal contamination
9. Counsel patient and family about potential long-term risks/effects (Linnemann, 2001; NCRP, 2001)

Radioactive contamination, internal or external, is never immediately life threatening and, therefore, **treatment of significant medical conditions should always take precedence over radiological assessment or decontamination of the patient**.

VII. Medical Management

Radiological casualties may include patients who have received a significant whole-body exposure and patients who have inhaled radioactive materials or who have wounds contaminated with radioactive materials.

Triage on the Scene (adapted from NCRP, 2001)
Treatment of life-threatening injuries always takes precedence over measures to address radioactive contamination or exposure. Contamination of a patient can be determined in the field, on the way to a medical facility or at the hospital. Patients who have received large absorbed doses may have symptoms such as nausea, vomiting, fatigue and weakness. These are also symptoms of exposure to many toxic materials and sometimes, psychological stress. Patients who have no evidence of external contamination, but are likely to have internal contamination due to a wound, inhalation or ingestion of radioactive materials, may be treated in routine emergency rooms. Blood, vomitus, urine or feces may be contaminated and should be handled using the procedures for contaminated materials.

Patients with large amounts of external or internal radioactive contamination must be given special attention because of the potential of exposure hazard to treatment personnel. Such contamination could occur from a detonation at a nuclear plant, the explosion of an RDD or a nuclear weapon detonation.

Individuals who are only externally contaminated, but not injured, should be decontaminated at a facility other than a hospital to conserve hospital resources for the injured (NCRP, 2001). Hospitals and other acute care treatment facilities treating patients on a walk-in basis should have plans in place for evaluating large numbers of the public for radioactive contamination. The plan must include several personnel with monitoring equipment who can make evaluations, keep appropriate records and still leave the emergency room free to handle severely injured patients (Mettler, 2002).

VIII. Patient Radiological Assessment

Patient management will depend on dosimetry, if available, and observed tissue response. Refer to Table 2 (Local Skin Absorbed Doses) and Table 3 (Total Body External Doses). When film badges, TLDs or other personal dosimeters are available they will support or provide dose data. When there are lower absorbed doses, there will be fewer biological findings. Personal dosimeters, accident reconstruction and history are important factors in determining levels of exposure (Linnemann, 2001).

The following is adapted from *Management of Terrorist Events Involving Radioactive Material* (NCRP, 2001).

A radiological assessment should be performed by an individual with radiological health training (e.g., a medical physicist), under supervision of medical personnel. This assessment includes radiation measurements and collection of information relevant to the decontamination and treatment of the patient. The instrument used to perform the survey should be sensitive to both penetrating and nonpenetrating radiation (e.g., a Geiger-Mueller tube with a thin wall or entrance window).

Table 2: Local Skin Absorbed Doses[1]
(adapted from Linnemann, 2001)

Condition	mrem	mSv	rem	Sv
Erythema	600,000	6,000	600	6
Dry Desquamation	1 million	10,000	1,000	10
Ulceration	2 million	20,000	2,000	20
Radiodermatitis	2.5 million	25,000	2,500	25
Epilation	300,000	3,000	300	3

[1] These dose-effect relationships are good approximations but can vary from individual to individual. They are energy dependent.

Epilation occurs 10 to 20 days post exposure

Pertinent information should be gathered about the terrorist incident, such as:

- When did it occur?
- What type and how much radioactive material may be involved?
- What medical problems may be present besides radionuclide contamination?
- What measurements have been made at the site (e.g., air monitors, fixed radiation monitors, nasal smear counts and skin contamination levels)?
- Are industrial, biological or chemical materials exposures expected in addition to radionuclides?

Questions about the status of the patient should include:

- What radionuclides now contaminate the patient?
- Where/what are the radiation measurements on the patient's surface?
- Was the patient also exposed to penetrating radiation? What has been learned regarding dosimetry?
- What is known about chemical and physical properties of the compounds containing the radionuclides (e.g., particle size, solubility)?
- Has decontamination been attempted and with what success?
- What therapeutic measures have been taken (e.g., use of blocking agents or isotopic dilution procedures?

Patient follow-up questions include:

- Has clothing removed at the site been saved?
- What excreta have been collected and where are the samples?
- What analyses are planned and when?

Good communication between medical personnel and the on-scene response team is critical (NCRP, 2001).

IX. The Externally Exposed Patient

In the absence of contamination, this patient can be admitted to any part of the emergency department without special precautions.

Local external exposures may result in skin manifestations. The doses required are large and usually result from brief radiation exposures.

Initial evidence of radiation damage is erythema which may be transient and then the main phase occurs 14 to 24 days later. Skin effects are often called radiation burns.

In contrast to thermal and chemical burns, pain is not associated with initial erythema of a radiation injury. Skin texture would initially be normal to sight and touch. Always take photographs of suspicious lesions.

Hair distribution is usually normal in the first few days. Epilation does not occur before 10 to 20 days post exposure. Little ER treatment is required for local exposures.

Consideration should be given to referring the patient to a radiation medicine specialist (e.g., nuclear medicine physician or radiation oncologist as appropriate) for follow up care.

In significant total body external exposure, the GI tract and the bone marrow are the organs of concern. Dose-effect relationships for the total body exposure are listed in Table 3.

The following discussion of total body external exposure is adapted from Linnemann (2001):

Below a dose of 100,000 mrem (100 rem or 1 Sv), patients are almost always asymptomatic. Above this dose, the time of onset and severity of symptoms are related to the total dose.

Table 3: Total Body External Doses*
(adapted from Linnemann, 2001)

Condition	mrem	mSv	rem	Sv
No observable effects	5,000	50	5	0.05
Chromosome damage[1]	15,000	150	15	0.15
White count depression	50,000	500	50	0.50
Symptom threshold[2]	100,000	1,000	100	1.00
Nearly 100% Lethality[3]	600,000	6,000	600	6.00

*For brief exposures of penetrating x-ray or gamma rays to the total body

[1] Seen in circulating lymphocytes

[2] Individual variations

[3] Without treatment

Except for overwhelming exposures (exceeding 500-800 rem or 5-8 Sv), the initial symptoms of the *acute radiation syndrome* (headache, malaise, anorexia, nausea and vomiting) usually don't appear until hours post exposure.

With doses greater than 200,000 mrem (200 rem or 2 Sv), symptoms of bone marrow depression will appear in about two to three weeks.

In addition to a general physical, the physician should order white blood cell counts with differential and a platelet count every three hours until a good dose estimate can be obtained.

If the patient is symptomatic or the initial dose is greater than 100 rem (1 Sv), the patient should be hospitalized and a radiation specialist notified immediately.

Asymptomatic patients with dose estimates less than 100 rem (1 Sv) can be followed on an outpatient basis. The patient and his/her family will be very anxious about the exposure. Therefore, early and continuous counseling regarding radiation effects will be required (Linnemann, 2001).

X. The Contaminated and Injured Patient
(adapted from Linnemann, 2001)

Treatment: The patient who is both contaminated and injured must be treated in the emergency department's Radiation Emergency Treatment Area (See Appendix C) where the patient can receive adequate medical care while the contamination is controlled. The Radiation Emergency Area is not necessarily a fixed location in the emergency department. It can be set up anywhere in the hospital, e.g., in the OR. It must always have an entrance, a treatment area, a buffer zone and an exit. The entire complex *must* be controlled. The flow of personnel, equipment and supplies is in one direction, from the clean part of the hospital into the controlled area. NOTHING and NO ONE leaves this area until properly surveyed for contamination. This includes blood samples, X-rays, etc. **Medical treatment for serious conditions always takes precedence over decontamination**. Contamination that is not visible to the naked eye – dirt, liquid, etc. – will not have enough radioactivity to cause early or visible radiation injury to the patient or attendant, and late effects are likely to be negligible. An unhurried approach to decontamination also is influenced by the fact that radiation intensity decreases with the passage of time (Linnemann, 2001).

With a survey meter, levels of contamination are measured in the following units:

cpm	cpm	Counts per minute
mrad/hr	mSv/hr	millirad (milliSievert) per hour
rad/hr	Sv/hr	rad (Sievert) per hour

The units as listed indicate an increasing amount of radiation exposure. Levels in the cpm range and millirad range are associated with a low level risk to the medical personnel. Only in the rad/hr (Sv/hr) range would it be necessary to institute more stringent radiation protective procedures in non-life saving situations. These include minimizing time spent near the patient, immediate gross decontamination of the patient by removing all clothing and wash down of the patient with copious amounts of water or saline in case of wounds.

Decontamination: One way to mentally prepare for the task of decontaminating a radioactively contaminated individual is to imagine that you are dealing with someone who has been contaminated with a large amount of bacteria which has a low pathogenic potential such as that contained in raw sewage. The sequence of steps you would follow to perform a safe and effective clean-up is similar in both cases.

Following any "quick decontamination" for the unusual high level of contamination, a more orderly management of the patient should begin. After stabilization, a careful survey of the naked body should begin. The amount of activity and its location are carefully recorded on anatomical burn type charts. Then, and only then, should an orderly decontamination begin.

Decontamination should be performed with the following priorities:

- Wounds
- Orifices
- High-level skin areas
- Low-level skin areas

How to Decontaminate: Ordinary soaps and copious amounts of water and/or saline are used to scrub the contaminated area. *The first attempt will usually remove 90% of the contamination*. All contaminated liquids are carefully collected in containers and saved for later disposal.

Continue a **survey-scrub-rinse** sequence until levels of contamination are less than 100 cpm over an area of 10 cm^2 or unless they fail to decline further.

Difficult areas of fixed contamination should be sealed off with gloves, plastic dressings, etc., and professional assistance sought.

Following decontamination, the patient should be evaluated for total body and skin exposure. **Depending on the clinical setting, a radiation specialist may need to be notified**.

XI. Radiation Counseling
(adapted from Linnemann, 2001)

Patients and medical personnel who have been exposed to ionizing radiation regardless of the reason or exposure level will be understandably concerned about the effects of this dose. These concerns will fall into four major categories:

- Acute effects
- Cancer risks
- Genetic risks
- Teratogenic risks

In order to produce acute effects, large doses over a brief period of time are required.

Table 4: Acute Effects of Radiation*
(Linnemann, 2001)

Condition	mrem	mSv	rem	Sv
No observable effects	5,000	50	5	0.05
Blood Abnormalities	15,000	150	15	0.15
Sperm Abnormalities	15,000	150	15	0.15
Nausea/Anorexia	100,000	1,000	100	1.00
Bone Marrow Depression	200,000	2,000	200	2.00
Epilation	300,000	3,000	300	3.00
Erythema	600,000	6,000	600	6.00

*Brief exposure (minutes to a few hours)

Contamination of the magnitude necessary to produce such large doses over a brief period of time is not likely to be seen on a live patient. (National Academy of Sciences, 1990)

Table 5: Long Term Effects of Radiation[1]
(Linnemann, 2001)

Effect	mrem	mSv	rem	Sv
Fetal Abnormalities*	10,000	100	10	0.10
Cancer*	10,000	100	10	0.10
Genetic	25,000	250	25	0.25
Cancer Death Risk 5%	100,000	1,000	100	1.00
Genetic Risk 1%	100,000	1,000	100	1.00
Cataracts 10%**	250,000	2,500	250	2.50

[1] Brief exposure (minutes to hours)
* Levels below which it becomes exceedingly difficult to consistently demonstrate effects
** 10% develop cataracts at this dose (gamma, x-ray)

For comparison, other common exposures are presented in Table 6 and Table 7.

Table 6: Typical Medical Doses*
(Linnemann, 2001)

Medical X-ray	mrem	mSv
Chest Study	10	.10
Cervical Spine	11	.11
Pelvis	27	.27
Skull	31	.31
Upper GI	117	.17
Barium Enema	298	2.98
CAT Scan	1800	18.00

* Effective doses. Doses vary depending on equipment, operator, etc.

Table 7: Environmental Doses*
(adapted from Linnemann, 2001)

	Dose	
	mrem	mSv
Natural background[1] (excluding radon)	100	1.00*
Radon inhalation[1]	200	2.00*
Television viewing	1	0.01
Air flight: New York-L. A**	4	0.04
Living within 50 mi. of nuclear plant	<1	<0.01
Chernobyl (avg. public exposure)[2]	1,500	15.00
Annual limit for radiation workers	5,000	50.00
Annual limit for public exposure	100	1.00
Average public exposure at TMI[3]	2 0	.02

1 Average annual dose in U.S.
2 Average calculated dose to 135,000 people living within 18 miles of the site
3 Average calculated dose to people living within 50 miles of Three Mile Island accident site
* Effective dose
**Per flight

The risks of radiation effects to treating personnel associated with a contaminated patient, if any, are commensurate with or below other risks commonly faced during the course of medical practice in most emergency departments (Linnemann, 2001).

Facilities treating contaminated patients should establish guidelines regarding exposure for medical personnel.

Teratogenic effects are particularly noteworthy because there *appears to be a threshold dose below which damage does not occur* (ICRP, 2000). This dose is about 10,000 mrem (10 rem or .1 Sv), a level seldom achieved in diagnostic X-ray or nuclear medicine procedures. As an additional precaution, the suggested limit during pregnancy is 500 mrem (5 mSv). When confronted with concerns about low levels of exposure, it may be helpful to compare the dose in question with the more familiar medical exposures (Linnemann, 2001).

Exposure Guidance for Emergency Responders in Terrorist Events

Special individual exposure guidance, often in excess of exposure limits (*i.e.*, 50 mSv [5000 mrem] per year for workers and 1 mSv [100 mrem] per year for members of the public), is required for emergency response operations because the benefits of establishing control at the scene are so great (NCRP, 2001).

NCRP Report No. 116 (NCRP, 1993a), *Limitation of Exposure to Ionizing Radiation,* includes the following broad guidance for emergency responders:

> "Normally, only actions involving life saving justify acute exposures that are significantly in excess of the annual effective dose limit. The use of volunteers for exposures during emergency actions is desirable. Older workers with low lifetime accumulated effective doses should be chosen from among the volunteers whenever possible. Exposures during emergency operations that do not involve life saving should, to the extent possible, be controlled to the occupational dose limits. Where this cannot be accomplished, it is recommended that a limit of 0.5 Sv (50 rem) effective dose and an equivalent dose of 5 Sv (500 rem) to the skin be applied, which is consistent with ICRP recommendations (ICRP, 1991).
>
> "When, for life saving or equivalent purposes, the equivalent dose may approach or exceed 0.5 Sv (50 rem) to a large portion of the body in a short time, the workers need to understand not only the potential for acute effects but they should also have an appreciation of the substantial increase in their lifetime risk of cancer. If internally deposited radionuclide exposures are also possible, these should be taken into account" (NCRP, 1993a).

See NCRP Report No. 138 (NCRP, 2001), chapter 8, for a detailed discussion of dose limitation and exposure guidance for terrorist events.

XII. Basic Rules for Handling Contaminated Patients

To summarize, the basic rules for handling ill or injured patients contaminated with radioactive material are:

1. **Treat life-threatening conditions first without regard to radiation or contamination.**
2. **Isolate the patient and restrict access to the treatment/evaluation area.**
3. **Maintain contamination control. Facilities should plan in advance and include the procedure in their Disaster Plan.**
4. **Obtain professional assistance from your facility's Radiology/ Nuclear Medicine/Radiation Safety Officer.**

Biological and Chemical Terrorist Agents: Radiological Findings

The following table, **Radiological Findings Associated with Biological and Chemical Threats to Public Health**, focuses on the radiological findings associated with disease or injury due to the most common agents of biological and chemical terrorism. For some syndromes, as indicated, there are no specifically related image findings associated with the effects of an agent.

If any of the infections or chemical injuries listed in the table is suspected, call the local health department immediately and institute appropriate precautions.

The reader who seeks additional information such as differential diagnosis, laboratory and test results, treatment or public health actions is referred to the following resources:

American Medical Association (AMA)
www.ama-assn.org

California Department of Health Services:
www.dhs.ca.gov/ps/dcdc/bt

Medical Management of Biological Casualties Handbook
www.nbc-med.org/SiteContent/HomePage/WhatsNew/MedManual/Sep99/Current/sep99.html

Medical Management of Chemical Casualties Handbook
www.vnh.org/CHEMCASU/titlepg.html

Table 8: Radiological Findings Associated with Biological and Chemical Threats to Public Health

Adapted from *Can you recognize these public health threats in your facility?* San Francisco Department of Public Health, 2001 http://www.medepi.org/sfdph/bt/syndromes/index.html and Ketai, et al, in press.

Syndrome	Bioterrorism Threat Disease Description	Initial Laboratory and Other Diagnostic Test Results
Acute Respiratory Distress with Fever	**Inhalation anthrax:** Abrupt onset of fever; chest pain; respiratory distress without radiographic findings of pneumonia; no history of trauma or chronic disease; progression to shock and death within 24-36 hours	Chest X-ray with widened mediastinum CT with enlarged hemorrhagic central nodes Images and additional information available from AFIP/INOVA Fairfax Hospital at: http://anthrax.radpath.org/
	Pneumonic plague: Apparent severe community-acquired pneumonia but with hemoptysis, cyanosis, gastrointestinal symptoms, shock	Variable CXR findings, most commonly include bilateral parenchymal infiltrates. Mediastinal, cervical and hilar adenopathy may be present in both bubonic and pneumonic plague.
	Ricin (aerosolized) Acute onset of fever, chest pain and cough, progressing to respiratory distress and hypoxemia; not improved with antibiotics; death in 36-72 hours	Chest X-ray with pulmonary edema that presents in about 18 hours and progresses to findings of severe respiratory distress with death from hypoxemia

Table 8: Continued

Syndrome	Bioterrorism Threat Disease Description	Initial Laboratory and Other Diagnostic Test Results
Staphylococcal enterotoxin B:	Acute onset of fever, chills, headache, nonproductive cough and myalgia (influenza-like illness)	Normal chest X-ray
Acute Rash with Fever	**Smallpox:** Papular rash with fever that begins on the face and extremities and uniformly progresses to vesicles and pustules; headache, vomiting, back pain, and delirium common	Pulmonary edema may occur with the flat and hemorrhagic form, possibly representing diffuse alveolar damage. In smallpox handler's lung, a mild form in previously vaccinated persons, CXR may show ill-defined nodular opacities in upper lung field.
	Viral Hemorrhagic Fever (e.g., Ebola): Fever with mucous membrane bleeding, petechiae, thrombocytopenia and hypotension in a patient without underlying malignancy	American Hantaviruses in early stage show interstitial edema on CXR. Severe cases show bilateral alveolar filling within 48 hours. CXR abnormalities are not common in illness caused by other VHFs.
Neurologic Syndromes	**Botulism:** Acute bilateral descending flaccid paralysis beginning with cranial nerve palsies	No specifically related image findings

Table 8: Continued

Syndrome	Bioterrorism Threat Disease Description	Initial Laboratory and Other Diagnostic Test Results
Neurologic Syndromes (continued)	**Encephalitis (Venezuelan, Eastern, Western):** Encephalopathy with fever and seizures or focal neurologic deficits.	MRI is more sensitive than CT, but both show abnormalities in area of basal ganglia and thalamus. MRI with T-2 weighted sequences show foci of increased signal in basal ganglia.
Influenza-like Illness	**Brucellosis:** Irregular fever, chills, malaise, headache, weight loss, profound weakness and fatigue. Arthralgias, sacroiliitis, paravertebral abscesses. Anorexia, nausea, vomiting, diarrhea, hepatosplenomegaly. May have cough and pleuritic chest pain.	CXR nonspecific: normal, bronchopneumonia, abscesses, single or miliary nodules, enlarged hilar nodes, effusions.
	Tularemia (Typhoidal, Pneumonic): Fever, chills, rigors, headache, myalgias, coryza, sore throat initially; followed by weakness, anorexia, weight loss. Substernal discomfort, dry cough if pneumonic disease.	Radiologic evidence of bronchopneumonia is usually evident. Lymphadenopathy and pleural effusions occur in one-third of patients. Acute radiographic changes may include subsegmental or lobar infiltrates, hilar adenopathy, pleural effusion, and apical or miliary infiltrates. Less common changes include ovoid densities, cavitation, and bronchopleural fistula.

Table 8: Continued

Syndrome	Bioterrorism Threat Disease Description	Initial Laboratory and Other Diagnostic Test Results
Blistering Syndromes	**T2 Mycotoxin:** Abrupt onset of mucocutaneous and airway irritation including skin (pain and blistering), eye (pain and tearing), GI (bleeding, vomiting, and diarrhea), and airway (dyspnea and cough)	No specifically related image findings. Patients can develop asthma and hemoptysis from airway irritation and have non-specific related findings.
Chemical Exposure	**Chemical agents:** Include mustards, nerve agents, phosgene, and unidentified chemicals	For guidance on management, visit the Web site of the Agency for Toxic Substances and Disease Registry (ATSDR) at: http://www.atsdr.cdc.gov/mmg.html

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National Council on Radiation Protection and Measurements. *Management of Terrorist Events Involving Radioactive Material.* Bethesda, Md: National Council on Radiation Protection and Measurements; 2001. Report No. 138.

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Web Resources

American College of Radiology
www.acr.org

American Medical Association (AMA)
www.ama-assn.org

California Department of Health Services
www.dhs.ca.gov/ps/dcdc/bt/

Medical Management of Biological Casualties Handbook
www.nbc-med.org/SiteContent/HomePage/WhatsNew/MedManual/Sep99/Current/sep99.htm

Medical Management of Chemical Casualties Handbook
www.vnh.org/CHEMCASU/titlepg.html

Medical Management of Radiological Casualties Handbook
www.afrri.usuhs.mil/www/outreach/pdf/radiologicalhandbooksp99-2.pdf

REAC/TS Radiation Emergency Assistance Center/Training Site
www.orau.gov/reacts

Federal and State Emergency Contacts

1. U.S. Nuclear Regulatory Commission
   www.nrc.gov

   NRC's 24-Hour Incident Response Operations Center:
   (301) 816-5100

2. U.S. Food and Drug Administration
   www.fda.gov/oc/opacom/hottopics/bioterrorism.html

3. Centers for Disease Control and Prevention
   www.bt.cdc.gov

4. U.S. Health and Human Services
   www.hhs.gov

5. State Emergency Management Directors
   www.fema.gov/fema/statedr.htm

6. Agency for Toxic Substances and Disease Registry
   www.atsdr.cdc.gov/2p-emergency-response.html

7. National Center for Environmental Health
   www.cdc.gov/nceh/divisions/eehs.htm

8. Federal Emergency Management Agency
   www.fema.gov

9. Conference of Radiation Control Programs Directors
   www.crcpd.org

Appendices

American College of Radiology

Appendix A

Treatment of Radiation Exposed Patients at General Hospitals

Type of Exposure	Possible Consequences	Initial Laboratory Treatment at a General Hospital
External Exposure		
Localized exposure, most often to hands	Localized erythema with possible development of blisters, ulceration, and necrosis	Clinical observation and treatment Securing of medical advice if necessary
Total or partial body exposure, with minimal and delayed clinical signs	No clinical manifestation for 3 hours or more following exposure Not life-threatening Minimal hematological changes	Clinical observation and symptomatic treatment Sequential hematological investigations
Total or partial body exposure, with early prodromal signs	Acute radiation syndrome of mild or severe degree depending on dose	Treatment as above plus securing of specialized treatment Full blood count and HLA typing before transfer to a specialized center
Total or partial body exposure, with thermal, chemical irradiation burns and/or trauma	Severe combined injuries, life-threatening	Treatment of life-threatening conditions Treatment as above and early transfer to a specialized center
External Contamination		
Low-level contamination, intact skin that can be cleaned promptly	Unlikely, mild radiation burns	Decontamination of skin and monitoring

Appendix A. Continued

Type of Exposure	Possible Consequences	Initial Laboratory Treatment at a General Hospital
External Contamination (continued)		
Low-level contamination, intact skin where cleaning is delayed	Radiation burns Percutaneous intake of radionuclides	Securing of specialist advice
Low-level contamination, with thermal, chemical, or radiation burns and/or trauma	Internal contamination	Securing of specialist advice
Extensive contamination, with associated wounds	Likely internal contamination	Securing of specialist advice
Extensive contamination, with thermal, chemical, or radiation burns and/or trauma	Severe combined injuries and internal contamination	First aid, plus treatment of life-threatening injuries; early transfer to a specialized center
Internal Contamination		
Inhalation and ingestion of radionuclides–insignificant quantity (activity)	No immediate consequences	Securing of specialist advice
Inhalation and ingestion of radionuclides–significant quantity(activity) of radionuclide	No immediate consequences	Nasopharyngeal lavage Early transfer to a specialized center to enhance excretion
Absorption through damaged skin (see under external contamination)	No immediate consequences	Securing of specialist advice
Major incorporation, with or without external total, or partial body, or localized irradiation, serious wounds and/or burns	Severe combined radiation injury	Treatment of life-threatening conditions and transfer to a specialized center

Source: Planning the Medical Response to Radiological Accidents, International Atomic Energy Agency, Safety Series Report No. 4, Vienna, 1998.

Appendix B

Radiation Accident Hospital Response

1. NOTIFICATION	• Number of patients • Type of injury/illness • Is the patient contaminated? • Staff/REA* preparation
2. PATIENT ARRIVAL	• Medical report • Radiological report • Clean team transfer
3. TRIAGE / EVALUATION / TREATMENT	• Cut away clothing • Isolate contaminated area
4. DRY DECONTAMINATION	• Remove contaminated articles from patient/staff
5. RADIOLOGICAL ASSESSMENT	• Survey/document • Sample orifices and contaminated areas/label
6. WET DECONTAMINATION	**Priorities** • Wound/orifices • Intact skin **Methods** • Drape • Wash • Rinse • Dry • Survey *Repeat as neccessary to reduce background level unless medically contraindicated*
7. PATIENT EXIT	• Clean pathway • Clean team transfer • Final survey at control line
8. STAFF EXIT	• Remove anti-contamination clothing • Survey at control line
9. REA CLEAN UP	

** Radiation Emergency Area*
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Appendix C

Stylized Map of Radiation Emergency Room