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REPORT

DEVELOPMENT OF A STATEWIDE HOSPITAL PLAN FOR RADIOLOGIC EMERGENCIES

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Although general guidelines have been developed for triage of victims in the field and for hospitals to plan for a radiologic event, specific information for clinicians and administrators is not available for guidance in efficient management of radiation victims during their early encounter in the hospital. A consensus document was developed by staff members of four Connecticut hospitals, two institutions of higher learning, and the State of Connecticut Department of Environmental Protection and Office of Emergency Preparedness, with assistance of the American Society for Therapeutic Radiology and Oncology. The objective was to write a practical manual for clinicians (including radiation oncologists, emergency room physicians, and nursing staff), hospital administrators, radiation safety officers, and other individuals knowledgeable in radiation monitoring that would be useful for evaluation and management of radiation injury. The rationale for and process by which the radiation response plan was developed and implemented in the State of Connecticut are reviewed. Hospital admission pathways are described, based on classification of victims as exposed, contaminated, and/or physically injured. This manual will be of value to those involved in planning the health care response to a radiologic event. © 2006 Elsevier Inc.

Radiologic emergencies, Radiation, Hospitals.

INTRODUCTION

Since the events of September 11, 2001, a widespread need has become apparent for providing professional advice to health care workers regarding measures to be undertaken in the case of an attack involving the exposure of people to radioactive material. Although general interim recommendations have been developed for hospitals to plan for a successful response to a radiologic event (1), little specific guidance is available to hospital personnel.

The Joint Commission on Accreditation of Healthcare Organizations requires that health care facilities develop plans to prepare for a response to a terrorist event (2). Such plans should permit coordination with the National Response Plan (3) that has been developed together with the National Incident Management System (4) to protect the public, limit damage, monitor extent and types of radioactivity present, perform decontamination, dispose of radioactive material, and make decisions regarding prophylaxis, evacuation, relocation, and shelter of radiation victims (5). Accordingly, hospitals and medical centers should develop medical response plans as part of their disaster planning effort that permit coordination of local, state, and national response resources.

Guidelines have been developed based on radiation dose estimates by the U.S. military for triage of radiation victims in the field (6, 7). Recommendations have also been made on the basis of clinical signs and symptoms of acute radiation syndrome (8) for triage of victims to a level of medical care (i.e., routine care, critical care, or transplant care) for hospitalized radiation victims (9). In addition, the importance of combining dose estimates with clinical signs and symptoms has been emphasized in assessing prognosis and

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planning therapy (7, 10–13). However, the application of these recommendations to evaluation and management of victims early in the hospital admission process is limited, because the guidelines lack specificity and fail to address throughput of victims in today's busy (and often overcrowded) hospital emergency department. They also assume that clinicians have a considerable knowledge of radiation measurements and radiation effects.

To address this gap in radiation response planning, a manual was developed for use by radiation oncologists, radiation safety officers, and emergency medicine personnel that uses the basic concepts of (*1*) exposure to radiation, (*2*) contamination by radiation, and (*3*) concomitant physical injury (including mechanical trauma and burns) for classification of victims presenting to the emergency department of Connecticut hospitals. On the basis of this classification system, victims should be quickly evaluated and assigned to a disposition status. This approach should result in timely and efficient processing of radiation victims, particularly when multiple victims must be managed in a short period.

The objectives of this report are to describe the process taken in the State of Connecticut to develop a template for radiation response planning for hospitals and to present a resulting manual that has been made available to hospitals in Connecticut for the purpose of modeling their emergency response plan. The manual provides recommendations concerning (*1*) delineation of responsibilities of different categories of health care professionals involved in the response, (*2*) protection of health care providers, (*3*) identification and classification of individuals who might have been exposed to and/or contaminated by radiation, and (*4*) early management of individuals who have had or might have had a radiologic exposure.

PROCESS FOR DEVELOPMENT OF STATEWIDE RADIATION RESPONSE PLAN

The State of Connecticut has a population of approximately 3.4 million people (14). Thirty-two acute care hospitals and two medical schools (the University of Connecticut School of Medicine and Yale University School of Medicine) are located in the state. Expertise in radiation detection and estimates of radiation dose is available in the Connecticut State Department of Environmental Protection. Additional expertise is present among hospitals where radiation safety officers and health physicists work. In addition, board-certified radiation oncologists work at 30 of the 32 acute care hospitals in the state. The state maintains one biodosimetry laboratory with the capability to assess dose by chromosome analysis.

Given the level of expertise in a state with a relatively small population, an opportunity for developing a statewide terrorism response plan for hospitals in Connecticut was identified. In early 2002, the State Commissioner of Health designated two centers of excellence for emergency response planning for a terrorist event: the Yale-New Haven Health System (YNHHS) and Hartford Hospital. An Office of Emergency Management for YNHHS was established in Bridgeport, Connecticut and later moved to New Haven, Connecticut. Acute care hospitals and community health centers in the state were assigned to a southern tier (whose center of excellence is YNHHS) or a northern tier (whose center of excellence is Hartford Hospital) for the purpose of terrorism response planning. Among the objectives of the centers of excellence was development of a radiation response plan.

Figure 1 provides a summary of the process of plan development. A small group of radiation "experts" was identified from employees of three of the hospitals comprising the YNHHS (including Bridgeport Hospital, Yale New Haven Hospital, and Greenwich Hospital). A series of meetings and discussions took place, and a draft plan was prepared by five individuals, including the chairpersons of the departments of medicine and emergency medicine, a radiation safety officer, a medical physicist, and a member of the State of Connecticut Department of Environmental Protection. The draft hospital plan was presented to an enlarged group of experts from around the state, including radiation biologists, radiation oncologists, medical physicists, radiation safety officers, and an officer of the American Society for Therapeutic Radiology and Oncology (ASTRO). This enlarged group comprised the Connecticut Radiation Response Planning Group, which included representation from Yale University School of Medicine, Hartford Hospital, the State of Connecticut Office of Emergency Preparedness, and the University of Connecticut Health Center. Through a series of monthly meetings, a consensus was developed over 8 months regarding an appropriate radiation response for hospitals. During these meetings, an emphasis was placed on the lack of individual "ownership" of the plan because the plan would be adopted by the State of Connecticut.

The draft plan was presented to the Executive Committee of the Yale New Haven Office of Emergency Management, the Southern Tier Committee of Connecticut hospitals, the

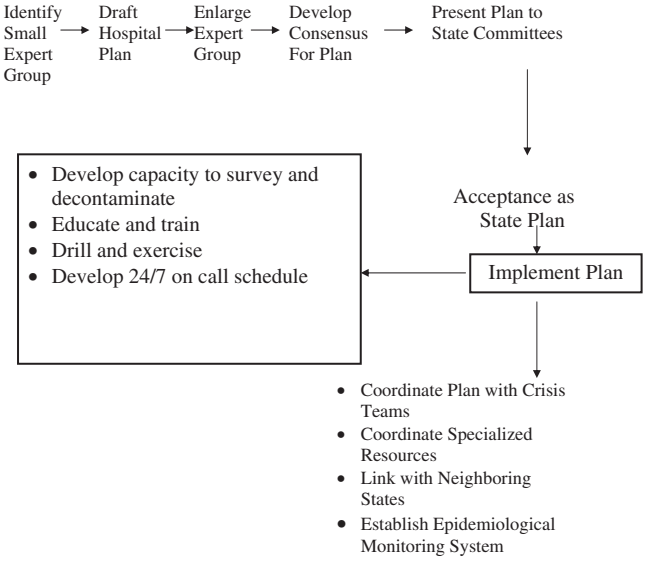

Fig. 1. Development of radiation preparedness program.

Northern Tier Committee of hospitals, and the Public Health Preparedness Advisory Committee for the State of Connecticut Commissioner of Health. After approval by each of these committees, the hospital model plan was adopted by the Commissioner of Health. An immediate need for updating training of radiation oncologists was identified by the ASTRO representative and other members of the Connecticut Radiation Response Planning Group. A "refresher course" was held in May 2003 for radiation oncologists in Connecticut and other states at the Radiation Emergency Assistance Center/Training Site (REAC/TS) in Oak Ridge, Tennessee. This training focused on recognition and management of acute radiation syndrome and radiation response planning. A member of the Connecticut Radiation Response Planning Group participated as a REAC/TS lecturer and discussion leader, addressing the role of the radiation oncologist in responding to a terrorist event involving radioactive material. Educational and training sessions have been developed, including tabletop exercises and drills for the Yale New Haven System and Hartford Hospital. A "24/7" on-call schedule for radiation oncologists has been developed. Educational programs for Connecticut radiation oncologists have been developed and delivered to "train the trainer." In turn, radiation oncologists will provide education to physicians and clinical staff of hospitals where they work through their respective hospital departments of medical education.

A formal curriculum entitled "Radiation Preparedness and Response for the Public Health and Hospital Workforce" was created by several members of the Connecticut Radiation Response Planning Group for students and educators at the University of Connecticut School of Public Health. The "Connecticut Model Radiation Emergency Manual for Hospitals" was used as part of the mandatory readings for students enrolled in the course for credit toward the master of public health degree. Lectures were attended not only by enrolled students but also by state public health workers, including directors and managers. A similar course is being developed for the Yale School of Medicine School of Public Health.

The following manual for emergency department workers and health care providers is directed at practicing clinicians (physicians, nurses, and paramedical caregivers) who have little familiarity with management of victims of a radiologic event. The manual is designed as an easy-to-use reference on what to look for, what to ask, and what to do when evaluating and treating individuals who might have been exposed to ionizing radiation. Appendixes to the manual are published in an electronic format and can be accessed through www.redjournal.org.

CONNECTICUT MODEL RADIATION EMERGENCY MANUAL FOR HOSPITALS

Scope of plan

This manual provides a standard protocol for health care providers in a hospital emergency department in the State of Connecticut. The protocol focuses on how health care workers should respond to patients who have been determined to have been exposed to a radioactive substance. The manual is organized into five broad areas: (*1*) early system response to notification of a radiologic event, (*2*) guidelines for classification, triage, and early management of people who might have had a radiologic exposure, (*3*) principles for processing individuals with radiation exposure, (*4*) responsibilities of different categories of professionals, and (*5*) policies and procedures for management of contaminated patients.

The response plan is based on the concept that personnel available in the emergency room are responsible for making initial decisions regarding activation of the standard protocol and initiating care of the patients, until individuals with specific expertise in radiation decontamination arrive. It assumes that nursing and physician personnel are familiar with basic concepts of triage and emergency management.

Response in the radiation field

In the case of a radiation event, individuals arriving on the scene of the incident will include members of the HAZMAT (hazardous materials) team, emergency medical services, and local fire and police departments (16). In Connecticut, members of the Department of Environmental Protection will also be called to the scene (see Appendix A). Communication between these "first responders" and hospital personnel will take place to provide a general appraisal of the type and number of victims who might arrive at the emergency room for evaluation and care (15).

Roles of health care providers

The primary individual responsible for initial activation of the standard protocol is the emergency department nurse supervisor. The nurse supervisor is responsible for assuring that the various aspects of the standard protocol are properly implemented. The primary individual responsible for the care of the patient is the emergency department medical director or, if unavailable, the emergency department physician assigned to trauma cases. This physician is responsible for assuring that medical and surgical care is administered in a timely and effective manner.

The primary individual responsible for radiologic monitoring is the radiation safety officer or his/her designee. These responsibilities include monitoring radiation doses of patients and response personnel, assessment of contamination of areas used in the administration of care to patients, and reporting of level of risk to clinicians and medical caregivers. Support for those implementing the standard protocol include nursing staff, housekeeping, security, hospital administrative staff, technologists, and physicians from the section or department of radiation oncology and/or the section or department of nuclear medicine and other physician specialists whose services might be required, as determined by medical personnel caring for the patients.

Basic concepts for care of radiation-exposed individuals

An individual can receive a radiation dose from an external source. Such an individual is not contaminated but

has been "exposed" to radiation. The danger to a victim depends on the radiation dose received and the period of time (or duration) of the exposure (16, 17). A person is "contaminated" when he/she has been physically covered by or has absorbed or ingested radioactive material. Contamination confined to the skin is considered to be external contamination, whereas that taken into the body through ingestion, inhalation, or transdermal absorption is considered internal contamination (15).

Unlike the toxicity from chemical or noxious gases, radiation causes little or no acute damage (7, 15). Therefore, life-threatening conditions should be treated without regard to radiation exposure or contamination (15). Medical therapy should include, in order of importance, (*1*) first aid and resuscitation, (*2*), medical stabilization, and (*3*) definitive treatment of serious injuries (15). Thereafter, other issues should be addressed, such as preventing or minimizing contamination, treatment of minor injuries, and treatment of internal contamination. If a radiation dose has been received from an external source, an exposed victim does not emit radiation. Thus, medical treatment should be the same as that for any other patient in the emergency department.

For victims who are exposed and contaminated with radioactive material, medical therapy for serious conditions always takes precedence over decontamination (15). Although contaminated individuals might emit small amounts of radiation from their body, the risks to health care givers are commensurate with or below the risks commonly faced during the course of medical practice in an emergency department. It is virtually impossible for a victim to be so heavily contaminated that he/she is a radiation hazard to health care providers (15).

Use of standard universal precautions (including surgical gloves, masks, shoe covers, and disposable gowns) protects health care providers from radiation contamination (15–18). A good approach to a contaminated individual is to act as though the victim has been contaminated with human blood, body fluids, or raw sewage. Treatment of injured victims should take place according to standard triage guidelines. All medical decisions should be based solely on the physical condition of the victim, regardless of radiologic contamination.

Preliminary decontamination of the victim includes simple procedures, such as removal of clothes and washing (7, 15, 17). Rarely, highly radioactive metal might be present in a body wound, in which case the metal should be removed (5, 15). Radiation victims should then be wrapped in a cloth sheet before transport to other areas of the hospital. Open wounds should be covered with waterproof dressings.

A calm and reassuring attitude is essential for the care of victims, family members, and friends (15, 19). Family and friends should be reassured that exposure to a contaminated victim is not a hazard to them. Psychosocial needs should be addressed through establishment of trust and open communication with the victim, family, and friends (20). A careful discussion with the patient about the early and long-term effects of radiation can be as important as any other

Medical stabilization of victim

Resuscitation and medical stabilization with definitive treatment of serious injuries takes precedence over decontamination of the skin, assessment and prevention of contamination, treatment of minor injuries, and containment of the treatment area (15, 17). Owing to an anticipated decline in circulating blood counts (including granulocytopenia and thrombocytopenia) within days or weeks after exposure to moderate- or high-dose radiation, victims requiring surgery for traumatic injury might be best managed by early surgical intervention rather than by delayed surgery (5, 7).

Critically injured victims might require direct access to the circulation for fluid administration, transfusion, medication, and collection of blood samples (5, 7). Intravenous and intra-arterial access sites can be secured (with local antisepsis as is routinely used for all patients) through contaminated skin. The amount of radioactivity introduced with a needle puncture is presumed to be minimal. If time permits, location of skin with a lesser degree of contamination (as determined by measurement with a Geiger counter) is preferred. The sites of traumatic injury, erythema, burns, and contamination should be documented on a body map, with the forms provided in Appendix C.

Contaminated penetrating metallic/radioactive fragments should be removed from the victim and placed in an appropriately marked container (15). Clinicians must wear appropriate protective clothing (e.g., gown, gloves, masks) and should remove radioactive or potentially contaminated fragments with forceps or other instruments without directly touching contaminated objects. After their removal, contaminated objects that have been placed in an appropriate receptacle will be monitored by the radiation safety officer and sent for storage in the nuclear medicine department or other appropriate radioactive storage area.

Local anesthetics and sutures can be used on contaminated skin and other organs, particularly in a life-threatening situation. Irrigation of the contaminated skin and wounds with normal saline is desirable. The effluent of normal saline should be collected in an appropriate container that is monitored by the radiation safety officer.

Open wounds that are free of contamination should be covered with a waterproof dressing to prevent cross-contamination. Contaminated wounds should be scrubbed gently with a surgical sponge and profusely irrigated. Debridement of contaminated tissue should be considered when surgically appropriate (5, 7).

Burns should be gently rinsed and covered (15). Over the next several days, the exudate will surface and carry with it much of the contamination into the dressing. Blisters should be left closed, whereas open blisters should be irrigated gently and treated according to appropriate burn protocols. A thorough washing of burns is not recommended. In addition to placing patients at risk for hypothermia and hypotension, such washing might remove potentially viable skin

and also might impress contaminants into the layers of dead tissue, placing the victim at risk for internal contamination (15). Burns are best managed by a surgical team with expertise in this area.

Documentation of historical information

In most events involving radioactive material, the emergency department entrance of the hospital will be accessed by victims. Essential information must be documented in the medical record of the emergency department. This information includes demographic data that is obtained routinely for evaluation of any patient treated in the emergency department.

Additional information concerning exposure to radiation should be documented, if known. This includes location of the incident, duration of exposure (i.e., number of days, hours, and minutes), interval between exposure and clinical evaluation (i.e., number of days and hours), number of individuals involved in the exposure, and sources of radiation (e.g., laboratory accident, medical spill, "dirty bomb") (7, 8). A general description of the accident should be documented, if known, including information regarding exposure to external penetrating radiation, contamination with radioactive debris on the body surface, or contamination by ingestion, absorption, or inhalation (7, 8). Physical properties of the radioactive compound(s) should be documented, including whether exposure occurred to a liquid, solid, or airborne particles. The activity of the individual at the time of the exposure and the occupation of the victim should also be documented (7, 8).

Recognition of a significant exposure

Symptoms and signs of a serious exposure have been identified (5, 7, 8). These include nausea and vomiting, rash, fever, headache, hypotension, neurologic deficits, impaired memory, and cytopenias (in particular, absolute lymphopenia). A physical examination should focus carefully on vital signs (fever, hypotension, orthostasis), skin examination (erythema, blistering, edema, desquamation), neurologic examination (ataxia, motor/sensory deficits, papilledema), gastrointestinal examination (abdominal tenderness), and a hematologic examination (ecchymoses and/or petechiae of mucous membranes and skin). An approximation of radiation dose can be made by determining the rate of decline in absolute lymphocyte count over the initial 24–72 h (21, 22).

Appendix D provides a summary table for recording the degrees of changes in each of the four systems that might be affected in acute radiation syndrome: the skin, the gastrointestinal system, the neurovascular system, and the hematologic system. Appendix D also provides additional tables for determining the severity (or degree) of toxicity to each of these systems. On the basis of on an integration of elements of the four systems, a radiation response category can be determined (8). On the basis of this category, the patient might be discharged from the emergency department, admitted to a routine care medical/surgical floor, or admitted to a critical care area of the hospital (9). For example, exposed individuals with absent or Level 1 severity for each of these four systems might be monitored in an ambulatory setting. Individuals who have Grade 3 or 4 severity of involvement of the cutaneous, gastrointestinal, and/or neurovascular systems will require hospitalization. Among these latter individuals, the presence of Grade 3 or 4 hematologic toxicity necessitates monitoring in a critical care area, such as the medical intensive care unit or surgical intensive unit (8, 9). Individuals with Level 2 severity of disease might be monitored in either an ambulatory setting or in the hospital (see Fig. 1 in Appendix D).

Classification of radiation victims

Victims should be classified according to whether they have been (*1*) exposed to external radiation, (*2*) contaminated after external exposure, and/or (*3*) physically injured. A radiation incident class is determined for each victim by the emergency department physician in conjunction with the aid of the radiation safety officer. Information provided by informed personnel at the scene of the accident is also used in assigning a class for each patient, as shown in Fig. 2.

Triage of radiation accident victims according to classification

Individuals who have not been exposed, contaminated, or injured are categorized as Class I. Although these individuals have no injury, psychosocial counseling should be considered. By contrast, victims who have been injured but who have not had exposure to or contamination with radiation are categorized as Class II. These individuals should be processed normally throughout the emergency department, and psychosocial counseling should be considered.

Victims who have been exposed to but are not contaminated by radiation are categorized as Class III (without physical injury) or Class IV (with physical injury). These individuals have received external exposure that might be of serious concern to the victim, family, and friends. Victims should be processed in the emergency department and initially treated for physical injury, if appropriate, as outlined below in Procedure A. Victims who are contaminated are categorized as Class V. As such, these individuals present a contamination hazard to the hospital. They should be taken to the portable decontamination area, where decontamination procedures should be followed. Patients should then be admitted through the emergency department, as outlined below in Procedure B.

Victims who are contaminated by radiation and also have physical injury are categorized as Class VI. The physician will determine the nature and seriousness of the injury. If the injury is life threatening, it must be treated before decontamination with the advice of the radiation safety officer and/or the radiation oncologist or nuclear medicine physician, who shall make recommendations on methods to minimize the spread of contamination. Victims should be admitted through the emergency department entrance to the hospital, as outlined below in Procedure C. Individuals whose exposure and/or contamination are unknown should

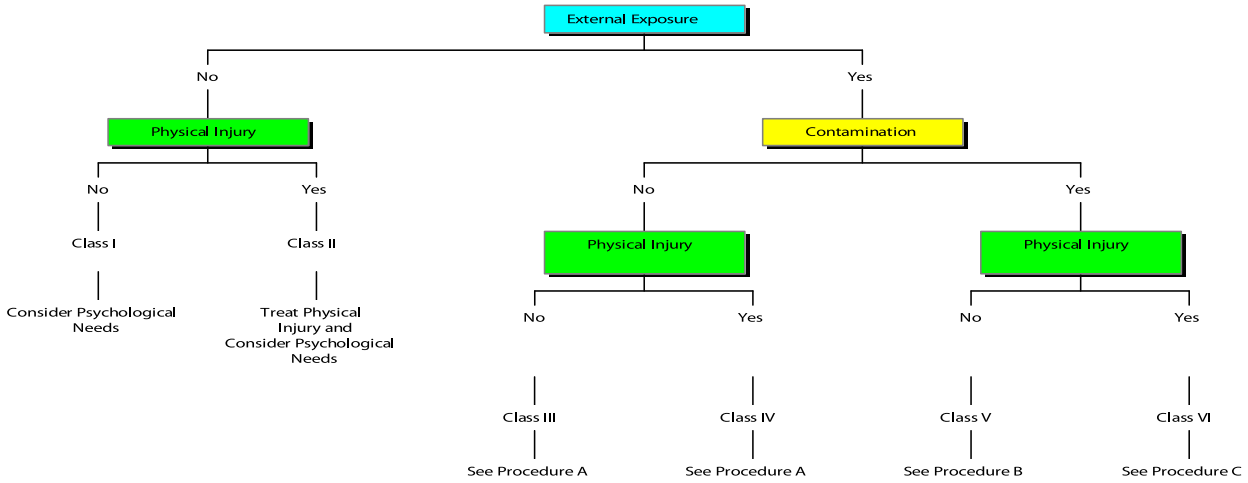

Fig. 2. Classification and evaluation of individuals who have received exposure to ionizing radiation.

be classified as Class VI until additional information is available.

Radiation accident evaluation/admission procedures

Procedure A should be followed for the evaluation and treatment of individuals who have been exposed to but are not contaminated by radiation, whether they have (Class IV) or have not (Class III) had physical injury. These victims should be evaluated without undergoing decontamination and admitted to the hospital, if significant clinical symptoms are evident (i.e., nausea, vomiting, diarrhea, anorexia, abdominal cramps, changing consciousness, memory impairment, pruritus, skin discomfort/pain, and bleeding into the skin, urine, or stool). Clinical signs and symptoms should be documented and graded by severity and frequency, as outlined in Appendix D. Blood samples should be drawn upon arrival at the emergency department (see Appendix E). Results of laboratory tests should be recorded (see Appendix F). In addition, the first urine passed after arrival should be saved and not mixed with subsequent specimens. This sample should be appropriately labeled and transported to the laboratory for future testing.

Procedure B should be followed for the evaluation and treatment of victims who have been contaminated but do not have physical injury (Class V). Decontamination should be performed only in the event that the local community's HAZMAT team has failed to decontaminate the victim or when contamination has been confirmed by expert hospital personnel. In most cases, an emergency department nurse might assume primary responsibility for activities within an area designated for radiation accident decontamination, until such time as when assistance can be obtained from the radiation safety officer, radiation oncologist, and/or nuclear medicine physician.

A portable decontamination shower should be used for the initial decontamination procedure. Housekeeping personnel should remove all nonessential furniture and equipment from this area. Plastic-lined waste containers (55-gallon or 30-gallon) should be placed in the decontamination area and labeled "Patient Clothes and Belongings" or "Contaminated Linen and Trash." Among those assigned to the medical decontamination area include a radiation safety officer and a radiation oncologist, a nuclear medicine physician and/or technologist, a registered nurse, and a licensed practical nurse or aide. Each member of the medical triage team should don a surgical scrub suit with plastic (Tyvek is recommended), surgical mask and cap, shoe covers, and disposable examination gloves before entering the decontamination area. The victim's clothing should be removed and placed in a plastic-lined waste container. First aid should be administered by the nursing staff members, and the medical triage team should survey for areas of contamination. Once areas of contamination have been delineated, the patient should be recycled through the decontamination process according to the procedures listed in Appendix G. Complete decontamination is generally not possible because some radioactive material can be fixed to the skin surface. The objective of contamination efforts is to lower contamination levels to a level twice that of background (background is considered to be <0.05 mR/h). Decontamination should be performed until the radiation level has reached twice the background level or until no further reduction in radiation level can be achieved (not to exceed three attempts).

After decontamination, the victim will be monitored by the radiation safety officer and/or the nuclear medicine technologist. No item within the decontamination area should be removed from this area without this item being monitored by these individuals. After decontamination, the victim should be admitted to the hospital for observation. Documentation of clinical symptoms (see Appendix D) and laboratory test results (see Appendix F) should be recorded at regular intervals.

Procedure C should be followed for the evaluation and treatment of victims who have been contaminated and who also have significant physical injury (Class VI). The emergency department physician will assume primary responsi-

bility for these victims, including supervision of immediate life-saving care. A designated elevator will be reserved in case of emergency transport of the patient to the operating room. A security officer should be posted at the elevator. A portable decontamination shower will be used for the initial decontamination of the victim. Plastic-lined waste containers will be used, as delineated in Procedure B. Ambulance personnel or vehicles involved in the transport of potentially contaminated individuals will not be permitted to leave the hospital grounds without being surveyed and wipe-tested by the radiation safety officer or nuclear medicine technologist, provided that the incident response does not require their further use. Contaminated vehicles will be secured and posted with a radiation warning sign and held for decontamination at a later time, provided that they are not needed for patient transportation. Contaminated ambulance personnel will require decontamination at the earliest possible time after response has been completed. The victim's clothing will be handled as delineated in Procedure B. Likewise, the process of decontamination will be followed as outlined in Procedure B. Upon removal from the decontamination area, the victim should be admitted to the hospital. Once admitted, blood samples and urine samples should be collected (see Appendix E).

Internal decontamination

Victims who have ingested, inhaled, or absorbed (transcutaneously) radioactive material require special decontamination measures (12, 13). As with therapy for victims who have received external contamination, treatment of victims with internal contamination requires that first aid, resuscitation, medical stabilization, and definitive care of serious injuries take precedence over internal decontamination. Internal decontamination can take place in a room marked with clear, easy-to-read signage in the hospital or in an ambulatory setting (see Appendix G).

Security

It is imperative that the decontamination area be kept physically isolated from the remainder of the hospital. Entry into and exit from this area must be restricted, and it must be assured that no contamination is transferred from this area to the remainder of the hospital. Before entry into this area, personnel *must* don the protective clothing described previously. Upon exit from the decontamination area, the protective clothing must be removed and considered contaminated. It shall be placed in a plastic-lined trash container for subsequent disposal or decay. In addition, all personnel *must* survey their hands, feet, and clothing before leaving the decontamination area with a survey meter, ensuring that they are not contaminated.

Imaging procedures

After all clothing has been removed and gross decontamination has occurred, the patient can be X-rayed (see Appendix H). If the patient is sufficiently decontaminated to be removed from the decontamination area, radiographic procedures can be performed within the emergency department or radiology department. If the treating physician believes that moving the patient from the decontamination area is unsafe, radiography can be performed with use of a portable X-ray unit. If the patient's condition warrants, radiographic procedures can be performed before complete decontamination.

Contaminated victims requiring surgery

Appendix I describes operating room safety procedures to be followed when patients who might be externally or internally contaminated require emergency surgery. All clothing and gross contamination must be removed in the decontamination area if the patient's condition allows. An operating room table will be prepared with appropriate plastic covering. A transport team that includes security and radiation safety personnel will be assembled before transport to the operating room, and a large blanket will be placed under and over the patient to contain contamination. The radiation safety officer or designee will be available to advise hospital personnel concerning contamination. A designated elevator will not be released to normal duty until surveyed and wipe-tested for contamination. All blankets, gowns, gloves, and other items potentially contaminated will be bagged, sealed, labeled as radioactive, and subsequently surveyed by the radiation safety officer or assistant. They will then be stored appropriately. The operating room staff will be notified concerning contamination levels and counseled regarding how to minimize risk of contamination. The operating staff will monitor hands, feet, and clothing with the assistance of the radiation safety officer or designee. Appropriate decontamination will be offered to hospital staff, if contamination is found.

The decontamination team

Before leaving the decontamination area, the victims and health care providers must be surveyed by the radiation safety officer or designee. The radiation safety officer and security personnel will determine the best route to be used in transporting patients who might not be fully decontaminated to various treatment areas of the hospital. At the end of the event or work shift, personal monitoring devices will be provided to the radiation safety officer for processing. The radiation safety staff will identify these monitors and record exposures as available. All contaminated items will be bagged, labeled, and stored in the appropriate storage area under the direction of the radiation safety staff.

Equipment—location and maintenance

Special equipment (listed in Appendix J) used for the care of contaminated patients beyond the scope of the usual emergency department inventory will be kept in a storage area (i.e., cabinet) marked "Hazardous Materials Equipment." This area should be located within close proximity of the emergency department. The key for entering this area should be held in a secure location. An

inventory list will be placed inside the cabinet. All monitoring equipment and radiation signs will be inspected and inventoried annually. Appendix K presents the relative risk, based on dose rate, to health care workers when providing care to cotanimated patients.

Psychosocial needs

Depending on the scenario, up to 75% of radiation victims have some symptoms requiring psychosocial support (6). These include insomnia, impaired concentration, and social withdrawal. Nonspecific somatic complaints and behavioral changes might occur, including fatigue, fear, avoidance of travel, and increasing substance use/abuse. In addition, acute stress disorder and posttraumatic stress disorder are common among victims, families, and friends (24). Those individuals at high risk for a psychological impact to an "invisible toxin," such as radiation, include children, pregnant women, mothers of young children, clean-up workers, and victims with a prior medical history of a psychiatric disorder (21).

Human resources that must be made available to the hospital include psychiatrists, psychologists, social workers, and hospice workers who can establish trust through open communication with the victim, family, or friends.

A particular concern for psychosocial support personnel is the psychological well-being of caregivers, including first responders, nursing staff, physicians, technicians, social workers, paraprofessionals, public health workers, and community volunteers. Generalized training in the mental health aspects of trauma is recommended for these individuals (16).

Responsibilities of hospital employees

The radiation safety officer will assist emergency department and triage staff in the determination of the classification of victims, provide guidance and preparation of decontamination space, direct and conduct survey, monitoring, and decontamination, estimate risk by measurement of dose rate, document and record all measurements, convey information of dose and risk to medical caregivers, and direct collection of blood and other biologic samples that might be required.

Nuclear medicine personnel will assist the radiation safety staff in the collection, storage, and analysis of samples, provide assistance and routine monitoring of personnel and equipment in the decontamination area, assist in the analysis of area and personnel contamination wipe tests, provide assistance in the monitoring of emergency transportation vehicles, and perform other duties related to radiation safety and protection, as directed by the radiation safety officer.

The hospital safety coordinator (administrator on call) will oversee the security operation to restrict unauthorized personnel from entering the hospital radiation decontamination area or other critical areas of the hospital, notify state or federal officials if the situation requires assistance in excess of the hospital's capacity, assign adequate personnel at the entrance of the hospital to restrict entry to the hospital to only those persons that are required for either operation of the hospital or implementation of the radiation disaster protocol, direct incoming ambulances to the proper hospital entrance as directed by the emergency department physician, radiation safety officer, or designees, secure the emergency medical services vehicle and prevent removal from hospital grounds until cleared by radiation safety staff, and reserve designated routes as needed.

Housekeeping personnel will remove nonessential items of furniture from the decontamination area before arrival of the accident victims. They will participate in space clean-up as directed by radiation safety staff.

Engineering staff will organize and set up decontamination area and provide plastic-lined waste containers and other supplies as needed in the emergency department for decontamination. Operating personnel, radiation oncology personnel, and laboratory personnel will assist as indicated, following the radiation protocol and direction of radiation safety staff.

Nursing staff will provide staffing in the emergency department, operating room, and elsewhere in the hospital and assist in decontamination, treatment, and psychological support of victims under the direction of radiation safety staff, emergency department staff, and hospital staff.

Postradiation disaster review

After completion of handling and decontamination of victims of a radiation accident, all personnel of the medical triage team and equipment used will be surveyed by radiation staff, and no person or equipment shall be allowed to exit from the decontamination area without appropriate monitoring. The decontamination space and other spaces in contact with contaminated victims will be surveyed and wipe-tested for contamination and decontaminated as needed. Radiation safety staff will direct decontamination of emergency transport vehicles, operating room, and elevators as needed. Hospitalized victims with persistent contamination will be surveyed daily and assessed for potential spread of contamination. Bed linen, bedclothes, and supplies will be bagged and surveyed. Personnel radiation monitoring devices carried by members of the team will be collected and analyzed. Radiation safety staff will estimate patient and staff dosimetry.

Resource materials

Background information regarding the diagnosis and management of individuals exposed to ionizing radiation is available in the literature (24–31) and at several web sites (32–35).

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APPENDIX A
LOCAL AND STATE RESPONSE TO DISPERSAL OF RADIOACTIVE MATERIALS BY A TERRORIST

Glossary

Atomic bomb – A weapon containing conventional high explosives and radioactive material that, after detonation, results in a nuclear reaction and release of radioactive isotopes of plutonium, uranium, and/or other elements, as well as neutrons and gamma rays.

Contamination – Deposition of radioactive material in any place where it is not desired. A person might be contaminated by absorption of radioactivity through the skin (transdermal), lungs (inhalation), or gastrointestinal tract (ingestion).

Decontamination – Reduction or removal of contaminating radioactive material from a physical structure, ground area, object or person.

Dose – A general term for the quantity of radiation or energy absorbed.

Dose rate – The dose delivered per unit of time. Often used to estimate the level of hazard from a radioactive source.

Dosimeter – A small device used for monitoring radiation exposure of personnel.

Exposure – (*1*) Receipt of a radiation dose from an external source. A person might be exposed to radiation (such as X-rays) but not contaminated with radiation; (*2*) a quantity used to indicated the amount of ionization in the air produced by X or gamma radiation. The unit is roentgen (R), which is generally similar in magnitude to a rad or rem.

External exposure – An exposure received from a source of ionizing radiation outside of the body.

Internal exposure – An exposure received from a source of ionizing radiation inside of the body.

Radiologic dispersion device – A device that is used to disperse radioactive material (such as a dirty bomb).

Radiologic dispersion event – A dispersal incident using a radiologic dispersion device, nuclear weapon, attack on a fixed nuclear facility (e.g., nuclear reactor, spent fuel storage depot, nuclear fuel reprocessing facility, transport vehicle, waste site) or attack on radioactive material in transit. Might involve localized sources released into the atmosphere or a water reservoir, or sources that are widely dispersed through the use of explosives.

Universal precautions – Use of disposable gowns, masks, gloves, and shoe covers to care for patients; these precautions, which were originally developed to protect health care workers from infectious diseases caused by blood-borne pathogens, also protect those treating persons who have been or might have been exposed to and/or contaminated with radioactive material.

General considerations and assumptions

Unlike other acts of terrorism, incidents involving the use of radioactive material often induce no or few nonspecific symptoms at the time of initial evaluation and triage. Victims of a conventional terrorist act involving explosives or incendiary devices have obvious trauma-induced lacerations, fractures, burns, and soft-tissue injury. Victims of an attack with a chemical agent often exhibit symptoms specific to that agent soon after the attack. By contrast, dispersal of radioactive materials results in casualties that are less obvious and more difficult to assess than those seen with other forms of trauma, particularly because victims might or might not be contaminated (i.e., by absorption of radiation through the skin after being physically covered by radioactive material or by ingestion or inhalation of radioactive material). Moreover, determination of radiation dose requires special expertise that is not generally found among health care workers.

Because radiologic contamination is invisible, terrorist events involving radioactive material can result in a substantial psychological impact. Attention must be paid not only to managing the immediate but also the long-term psychosocial effects of an attack. Several assumptions are made in the radiation response plan, as follows:

- A radiologic event might involve one or multiple municipalities in Connecticut, resulting in an impact on the health care provided by one or more Connecticut hospitals.
- A radiologic event might occur with no advanced warning.
- Individuals and organizations arriving at the scene immediately upon a radiologic event include members of the hazardous materials (HAZMAT) team, including the local police department, emergency medical services, local fire departments, and the Connecticut Department of Environmental Protection (DEP).
- The local fire chief will most likely be one of the people, if not the first person, on the scene of a radiologic incident. The fire chief, along with the local police chief and the radiologic expert from the DEP, will be the unified commanders for the event, unless/until relieved by a higher authority. The DEP will notify federal authorities of the event.
- For larger radiologic incidents, the DEP will request assistance from the New England Radiologic Health Compact and/or the Department of Energy.
- Assessment of type(s) and amount(s) of radioactive agent(s) will be made at the site of the incident by members of the DEP.
- Whenever possible, decontamination of victims who are only externally contaminated will take place at a designated decontamination station before arrival at the hospital.
- Victims of terrorist events involving radioactive material might exhibit no initial symptoms or only nonspecific symptoms (e.g., nausea, anorexia, headache, cognitive deficits, or fever).
- Owing to the inherent fear of the general public to exposure to radioactivity, many victims will have psycholog-

ical shock in the setting of exposure to a very low dose of radiation or even to a dose that is at the normal background level of radioactivity in the environment.
- Management of a radiologic event requires that health care professionals act in a calm and organized fashion to obtain pertinent historical information from the victims and to identify signs of significant exposures.

Equipment and supplies

Equipment to detect and measure the amount of radioactivity (and thereby estimate the radiation dose to a victim or caregiver) is required for each Connecticut Hospital. This includes personal monitoring devices for triage personnel (approximately 10–20 devices per hospital) and possibly pocket dosimeters (part of the civil defense kit). In addition, each hospital should be equipped with two to three Geiger counters (with thin end window probe to measure low-energy radiations) to be operated by responsible and knowledgeable persons. Geiger counters must be inspected and calibrated annually.

The following equipment is also recommended (but not required). In the case where a hospital does not have the following equipment and/or expertise in using such equipment, arrangements with another Connecticut hospital to provide such expertise, and monitoring services shall be made.

- One ion chamber per hospital.
- Hospitals should be equipped with the capacity to perform wipe tests.
- Access to spectroscopy equipment and expertise is recommended for identification of radionuclides in biologic samples. No special supplies are required for managing a radiation incident. Disposable gowns, gloves, masks, and shoe covers are required, as is usual for the protection and infection control measures used in every Connecticut hospital today.

Decontamination

Decontamination facilities are required for victims who have been contaminated with radioactive material. The facilities required for such decontamination are identical to those required for decontamination of a victim of chemical terrorism. Decontamination can take place either inside or outside, and consists of running water at high volume with hand soap and subsequent drainage of the effluent into a self-contained collection system or storm sewers. Decontamination trailers can be provided to both the scene and the hospitals through the implementation of the Statewide Decontamination Mobilization Plan. Units delivering trailers will have radiologic monitoring devices, whose use will require an informed first responder who is trained in the proper use of this equipment. Hospitals have been provided portable decontamination equipment constructed of polyvinyl chloride piping and curtains capable of decontaminating 60–80 victims in 1 h.

Every effort will be made to provide decontamination before arrival at a Connecticut hospital. In the event that such services are unavailable for a victim, decontamination should take place at the hospital. The hospital receiving victims should be informed by the on-the-scene triage team of the number of patients, a brief description of their injuries, contamination status, and whether or not decontamination has taken place before their arrival at the hospital.

Pharmaceuticals

Hematopoietic growth factors (i.e., cytokines) have been demonstrated to accelerate the rate of hematopoietic recovery in victims exposed to moderate or high doses of radiation. Early therapy (within 24–72 h of exposure) with a single growth factor or a combination of growth factors (for example, granulocyte colony-stimulating factor [GCSF] or GCSF and granulocyte-macrophage colony-simulating factor) results in significantly faster recovery from cytopenias in radiation accident victims. Therefore, hospital pharmacies should have "on hand" each of these cytokines in an amount to treat 4–6 victims for 2–4 days, at which time additional growth factors should become available. The Centers for Disease Control and Prevention have included GCSF in its strategic national stockpile of pharmaceuticals that will be made available in the case of a terrorist event involving radioactive material.

Preventative administration of broad-spectrum antibiotics to neutropenic individuals improves the mortality rate from sepsis. Preclinical studies in irradiated large animals show that early administration of broad-spectrum antibiotics increases survival. Connecticut hospital pharmacies are routinely stocked with broad spectrum antibiotics that may be useful in the management of radiation incident victims including fluoroquinolones, cephalosporins, and aminoglycosides. Antiviral and antifungal agents such as acyclovir and Diflucan that might be indicted in the treatment of radiation victims with immune suppression are also routinely stocked in hospital pharmacies.

A radiologic dispersal event might involve localized sources (e.g., a small ampule or small container) or more widely dispersed sources resulting from explosion of a large amount of radioactive material. For "dirty bombs," sources of radioactivity are unlikely to include radioactive iodine (which is a radionuclide component of nuclear reactor materials). Because a "dirty bomb" will not have radioactive iodine, potassium iodide (KI) is not recommended in a response to terrorist event involving these devices.

It is extremely unlikely that a nuclear power plant will be successfully attacked by terrorists. The Nuclear Regulatory Commission has provided guidance to nuclear power plants with regard to storage and distribution of KI tablets. Potassium iodide has been distributed to Connecticut residents residing within 10 miles of a nuclear power plant. Potassium iodide tablets can also be obtained by the public at specialized reception centers. Additional KI has been prestocked at public and private schools within 10 miles for administration to children. In selected scenarios, relocation of children will be undertaken before plume arrival.

Should radioactivity be released from a power plant, KI should be administered to those within a 10 mile radius of the plant. The dosage of 16 mg for infants aged <1 month, 32 mg for children aged <3 years, 65 mg for children and adolescents aged 3–18 years, and 130 mg for all individuals aged >18 years, should be administered daily for 2 weeks while exposure to radioactive iodine continues. Once the exposure ceases, the need for continued KI also ceases.

Education

In addition to annual medical and surgical grand rounds and the equivalent for nursing grand rounds for the general medical/nursing staffs, health care workers in the following areas should receive specialized training: emergency department, trauma section, critical care areas, security, and transportation. Education can be provided through a computer-based training program developed by the U.S. Department of Energy's Emergency Operations Training Academy. Specific courses have been developed for Connecticut hospitals by the Yale New Haven Health System Office of Emergency Planning. Other forms of ongoing training should include educational drills focusing on recognition of a significant exposure to ionizing radiation, diagnosis of the acute radiation syndrome, and appropriate triage in the emergency department and in the hospital. Additional training should focus on psychological support and on the psychosocial impact of a terrorist event involving radioactive material.

Public communication

An event involving the dispersal of radioactive material, either through a terrorist event or an accident, will necessarily involve providing information to the general public. This will generally be through the news media, which will rightly pursue all avenues to learn details of the event, the number of patients admitted and treated, the nature of injuries, risks to the public, remediation plans, and other related information. It is imperative that information provided is correct, provided in a manner easily understood by the general public, and consistent with information provided by responding agencies. It is also imperative that personal medical information not be released or specific patients identified.

Medical facilities should plan for such events by identifying one individual (public information officer or equivalent) to be the spokesperson for activities occurring within the medical facility. Staff should be instructed not to respond to inquiries from the press or general public, but rather to refer such inquiries to the public information officer. A location, removed from the immediate area of patient treatment, should be established for the press to gather to receive updates from the public information officer. Only that information directly related to activities at the medical facility should be provided. Questions regarding emergency response at the scene of the event, remediation actions, impacts and doses, and risks to the general public should be directed to the State of Connecticut's Emergency Operations Center, which will be established at the National Guard Armory located in Hartford (860-566-3180).

Should such an event occur, it is imperative that access to the emergency department (or other treatment and/or decontamination area) be restricted quickly so that only authorized individuals can gain entry. Various agencies involved in a terrorist event can make decisions that restrict the information that is provided to the public. That is, information that might involve crime scene evidence, impact the public safety, or assist terrorists should not be released. Care should be taken to prevent the taking of photographs and/or video by unauthorized individuals.

APPENDIX B
TELEPHONE NOTIFICATION LIST

1. Radiation safety officer and/or radiologist.
2. Nuclear medicine physician and/or radiation oncologist.
3. Activate disaster plan (if mass accident).

APPENDIX C

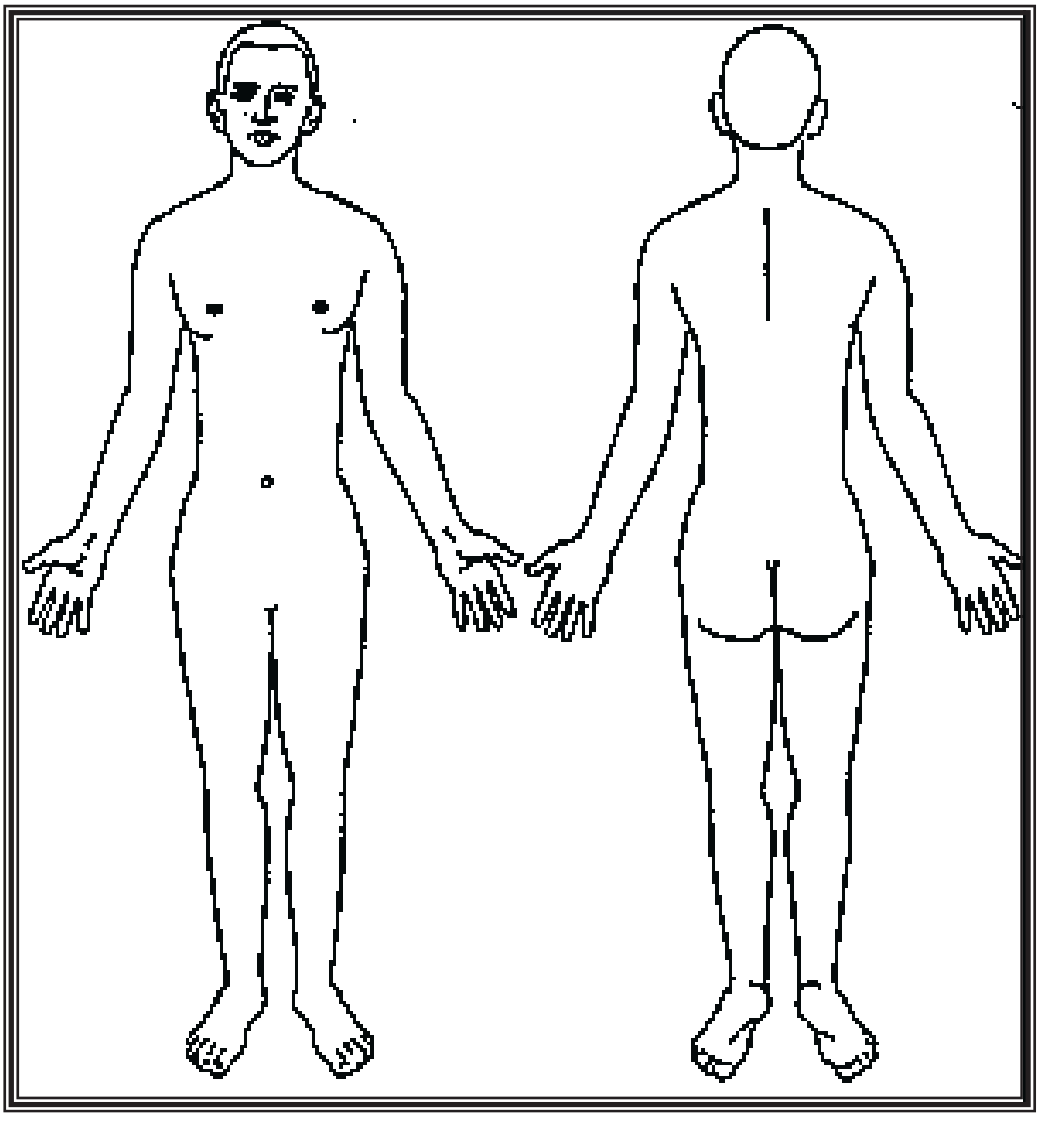
Name _____ Examination:
Date: _____ Time: _____

Medical Record No._____

Exposure:
DOB: _____ Date: _____ Time: _____

Gender: Male θ Female θ Contamination: Yes θ No θ

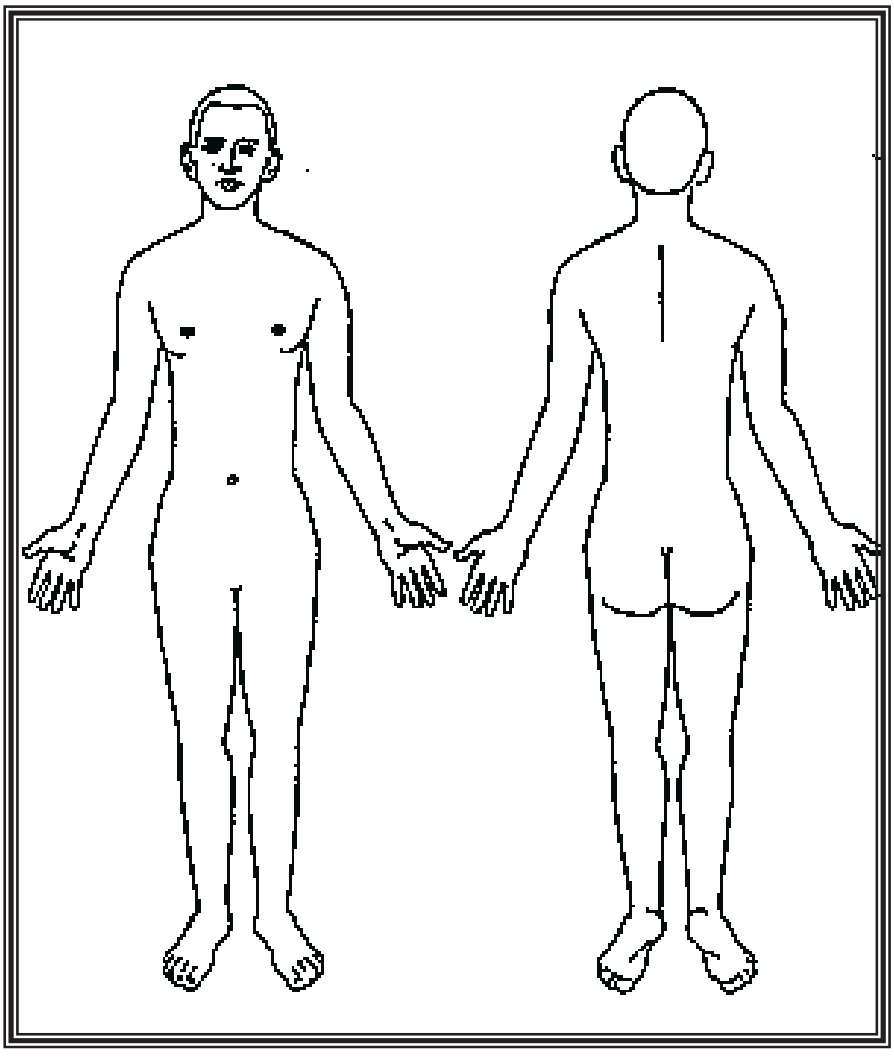
SITES OF TRAUMA/ERYTHEMA
(Identify area by number)



1. Abrasion
2. Amputation
3. Avulsion
4. Erythema
5. Burn
6. Edema
7. Contusion
8. Crepitus
9. Laceration
10. Fracture

Name _____ Examination:
Date: _____ Time: _____

SITES OF CONTAMINATION



Samples obtained from:

Site	Date
θ Nose	_____
θ Mouth	_____
θ Wound	_____
θ Skin	_____
θ Urine	_____
θ Clothing	_____
θ Other:_____	_____

Radionuclides identified:

_____

_____

Other hazardous materials:

_____

_____

APPENDIX D

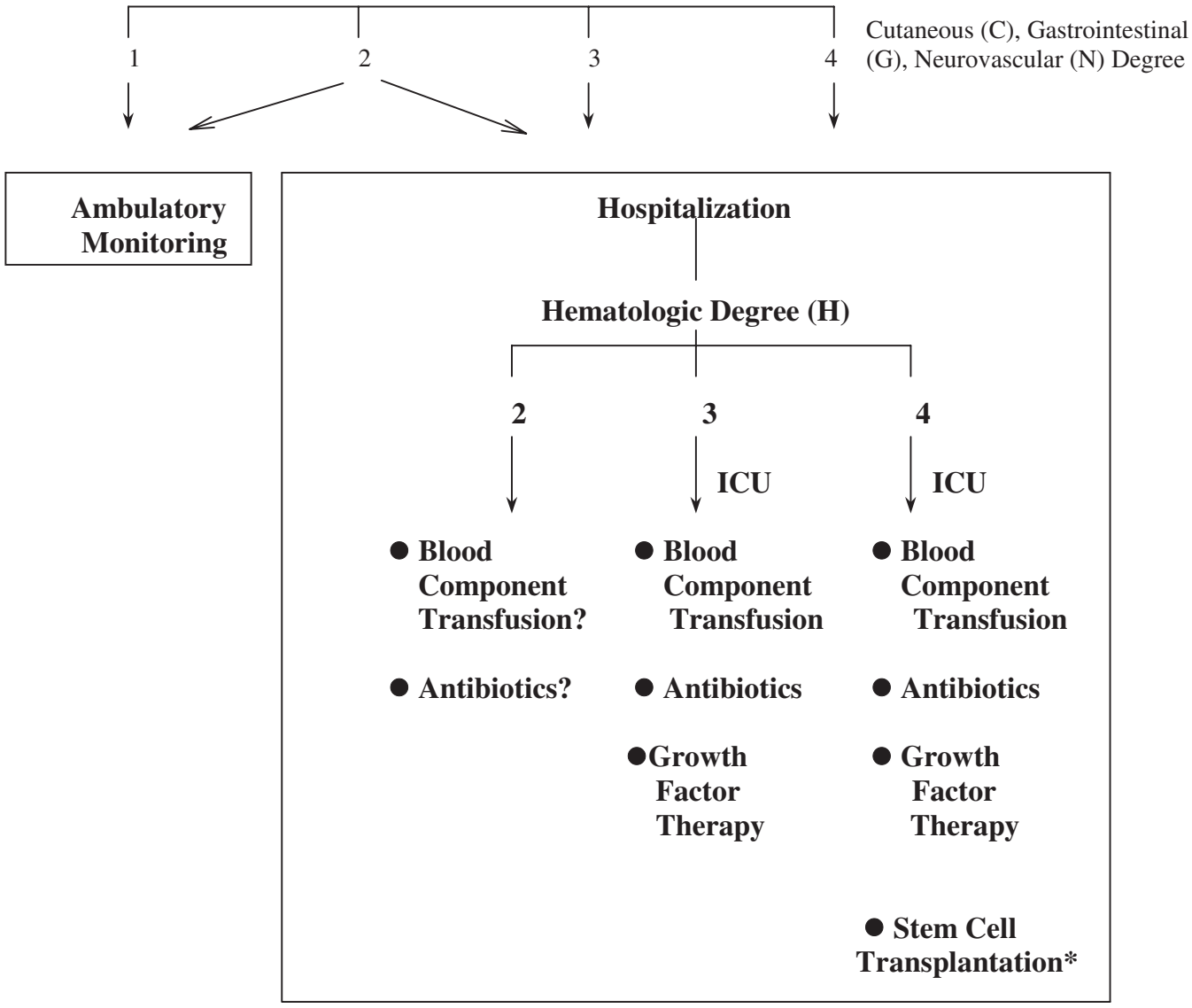


Fig. 1. General approach to triage and therapy of radiation incident victims. Systems include cutaneous system (1: minimal, transient rash; 2: moderate rash of <10 cm^2, $<10\%$ body surface area [BSA]; 3: marked rash, 10–40% BSA with onycholysis; 4: severe rash, $>40\%$ BSA with onycholysis); gastrointestinal system (1: 2–3 stools/d with minimal abdominal pain; 2: 4–6 stools/d with moderate pain; 3: 7–9 stools/d with severe pain; 4: 10 stools/d with excruciating pain); and neurovascular system (1: mild nausea with vomiting 1×/d, blood pressure (BP) $>100/70$, normal neurologic examination; 2: vomiting 2–3×/d, BP $<100/70$ and $>90/60$, focal neurologic deficits, and memory loss; 3: vomiting 6–10×/d, BP 90/60 and >80, palpable, prominent neurologic deficits, major intellectual impairment). Further triage based on changes in the hematologic system includes: 1: lymphocytes $>1{,}500 \times 10^6$/L, granulocytes $>2{,}000 \times 10^6$/L, platelets $>100{,}000 \times 10^6$/L; 2) lymphocytes 1,000–5,000 $\times$ 10^6/L, granulocytes 1,000–2000 $\times$ 10^6/L, platelets 50,000–100,000 $\times$ 10^6/L; 3: lymphocytes 500–1,000 $\times$ 10^6/L, granulocytes 500–1,000 $\times$ 10^6/L, platelets 20,000–50,000 $\times$ 10^6/L; and 4: lymphocytes $<500 \times 10^6$/L, granulocytes $<500 \times 10^6$/L, platelets $<20{,}000 \times 10^6$/L. *Presence of G4, C4, and/or N4 degree indicates probable death. Supportive therapy alone is indicated (fluids, blood components, antibiotics, pain Rx, counseling). Modified from Dainiak (9).

Table 1. Use the following template to document symptoms as a function of time. Use a scale of 1–4 (see attached pages). Copy as required

Patient ID:		Date/time of exposure:				Examiner:		
Date and time of examination								
N	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity
Nausea								
Vomiting								
Anorexia								
Fatigue syndrome								
Fever								
Headache								
Hypotension								
Neurologic deficits								
Cognitive deficits								
Maximum								
Grading N								
H	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity
Lymphocyte changes								
Granulocyte changes								
Thrombocyte changes								
Infection								
Blood loss								
Maximum								
Grading H								
C	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity
Erythema								
Sensation/itching								
Swelling/edema								
Blistering								
Desquamation								
Ulcer/necrosis								
Hair loss								
Onycholysis								
Maximum								
Grading C								
G	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity	Degree of severity
Frequency (stool)								
Consistency (stool)								
Mucosal loss/d (stool)								
Bleeding/d (stool)								
Abdominal cramps/pain								
Maximum								
Grading G								
Grading Code	N H C G	N H C G	N H C G	N H C G	N H C G	N H C G	N H C G	N H C G
Radiation category								
Days after exposure								

Abbreviations: N = neurovascular system (Table 2); H = hematologic system (Table 3); C = cutaneous system (Table 4); G = gastrointestinal system (Table 5).

Modified from Fliedner *et al.* (8).

Table 2. Neurovascular system

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
Nausea	Mild	Tolerable	Intense	Excruciating
Vomiting	Occasional, 1/d	Intermittent, 2–5/d	Persistent, 6–10/d	Refractory >10/d
Anorexia	Able to eat, reasonable intake	Significantly decreased intake but able to eat	No significant intake	Parenteral nutrition only
Fatigue syndrome*	Able to work or perform normal activity	Interferes with work or normal activity	Needs some assistance for self-care	Prevents daily activity
Fever	<38°C	38°C–40°C	>40°C for <24 h	>40°C for >24 h or accompanied with hypotension
Headache	Minimal	Tolerable	Intense	Excruciating
Hypotension	HR > 100/BP > 100/70	BP < 100/70	BP < 90/60; transient	BP < 80/?; persistent
Neurological deficits†	Barely detectable neurological deficit; able to perform normal activity	Easily detectable neurological deficit, no significant interference with normal activity	Prominent neurological deficit, significant interference with normal activity	Life-threatening neurological signs, loss of consciousness
Cognitive deficits	Minor loss of memory, reasoning and/or judgment	Moderate loss of memory, reasoning and/or judgment	Major intellectual impairment since accident	Complete memory loss and/or incapable of rational thought

Abbreviations: HR = heart rate; BP = blood pressure.

* Fatigue: self-recognized state of overwhelming, sustained exhaustion and decreased capacity for physical and mental work—not relieved by rest. Typical descriptions are drained, finished off, lethargic, beaten, exhausted, or worn out, prostration, drowsiness. Components are physical, cognitive, emotional/affective.

† Neurological deficits; reflex-status md. Reflexes of the eye, ophthalmoscopy (edema of papilla), fainting, dizziness, ataxia, and other motor signs, sensory signs.

Table 3. Hematologic system

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
Lymphocyte changes*	*1,500 × 10^6/L	<1,500–1,000 × 10^6/L	<1,000–500 × 10^6/L	<500 × 10^6/L
Granulocyte changes†	*2,000 × 10^6/L	<2,000–1,000 × 10^6/L	<500–1,000 × 10^6/L	<500 × 10^6/L or initial granulocytosis
Thrombocyte changes‡	*100,000 × 10^6/L	<100,000–50,000 × 10^6/L	<50,000–20,000 × 10^6/L	<20,000 × 10^6/L
Blood loss	Petechiae; easy bruising; normal Hb	Mild blood loss with <10% decrease in Hb	Gross blood loss with 10–20% decrease in Hb	Spontaneous or blood loss with ≥20% decrease in Hb

Abbreviation: Hb = hemoglobin.

Modified from Dainiak (9) and Fliedner *et al.* (8).

* Reference value: 1,500 × 10^6/L.

† Reference value: 4,000–9,000 × 10^6/L.

‡ Reference value: 140,000–400,000 × 10^6/L.

Table 4. Cutaneous system

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
Erythema*	Minimal and transient	Moderate; isolated patches <10 cm^2; not more than 10% of body surface (BS)	Marked; isolated patches or confluent; 10–40% of BS	Severe†; isolated patches or confluent; >40% of BS
Sensation/itching	Pruritus	Slight and intermittent pain	Moderate and persistent pain	Severe and persistent pain
Swelling/edema	Present; asymptomatic	Symptomatic; tension	Secondary dysfunction	Total dysfunction
Blistering	Rare, with sterile fluid	Rare, with hemorrhage	Bullae with sterile fluid	Bullae with hemorrhage
Desquamation	Absent	Patchy dry	Patchy moist	Confluent moist
Ulcer/necrosis	Epidermal only	Dermal	Subcutaneous	Muscle/bone involvement
Hair loss	Thinning, not striking	Patchy, visible	Complete and most likely reversible	Complete and most likely irreversible
Onycholysis	Absent	Partial	Partial	Complete

* With respect to assessing the cutaneous system, the extent of the skin area affected is decisive and should be documented for all skin changes.

† Only for penetrating irradiation. Changes in the skin pigmentation might also occur. However, given the lack of reference data describing de- or hyperpigmentation, this symptom is not included in the grading. Nevertheless, it should be recorded systematically, as it might be helpful in future radiation accidents.

Table 5. Gastrointestinal system

Symptom	Degree 1	Degree 2	Degree 3	Degree 4
Diarrhea				
Frequency	2–3 stools/d	4–6 stools/d	7–9 stools/d	$\geq$10 stools/d; refractory diarrhea
Consistency	Bulky	Loose	Loose	Watery
Mucosal loss/d	Intermittent	Intermittent with large amount	Persistent	Persistent with large amount
Bleeding/d	Occult	Intermittent	Persistent	Persistent with large amount
Abdominal cramps/pain	Minimal	Tolerable	Intense	Excruciating

APPENDIX E
LABORATORY TESTS

- Complete blood count (CBC) with differential and calculation of absolute lymphocyte count
- Platelet count
- Electrolytes, creatinine, blood urea nitrogen, liver function tests
- Spectroscopy to determine radionuclides in urine sample
- Cytogenetics (draw blood and hold in laboratory)
- Human leukocyte antigen typing (draw blood and hold in laboratory)

BIOLOGIC SAMPLES

For external exposure or external contamination

1. Peripheral blood
   a) 5 mL in ethylenediaminetetraacetic acid (for CBC, absolute lymphocyte count, reticulocytes)
   b) 5 mL in heparin (for electrolytes and renal function tests)
   c) 10 mL in heparin in hermetically sealed flask (for cytogenetics)
2. Urine: first-passed after accident. Should not be mixed with subsequent specimens. Date and time of collection should be recorded.

For internal contamination

1. Peripheral blood
   a) Same as for external exposure plus "b" and "c."
   b) 20 mL in empty tube (without preservative)
   c) 10 mL in heparin
2. Urine
   a) Same as for external exposure plus "b"
   b) 24-h urine collection
3. Feces: collect all stools passed during first 72 h
4. Nasal smears: swab nose and label with date/time of sample collection. Nasal swab specimens represent approximately 5% of radioactivity presumed to be deposited in the lungs.
5. Other: handkerchiefs, induced sputum, spontaneous vomitus (do *not* induce vomiting)

APPENDIX F

This template gives an overview of the laboratory tests to be performed repeatedly and documented as a function of time to capture the dynamics of a potential acute radiation syndrome. Copy as required.

Patient ID:	**Date/time of exposure:**	**Examiner:**

Date and time of Blood collection										
Key hematologic values										
Granulocytes										
Lymphocytes										
Platelets										
Additional hematologic parameters										
Hemoglobin										
Hematocrit										
MCV										
Reticulocytes										
Laboratory tests										
Sodium										
Potassium										
Chloride										
CO_2										
Creatinine										
BUN										
Stool OB										
AST										
ALT										
Alk. Phos.										
Bilirubin (T/D)										

Abbreviations: MCV = mean corpuscular volume; BUN = blood urea nitrogen; OB = occult bleeding; AST = aspartate aminotransferase; ALT = alanine amino transferase; Alk. Phos. = alkaline phosphatase; T/D = total/direct.

APPENDIX G
DECONTAMINATION PROCEDURES

1. Gross whole-body contamination
   a) Put on examination gloves.
   b) Remove clothing of patient.
   c) Mark and localize areas of contamination as determined by Geiger-Mueller survey.
   d) Cover open wounds, if present, with plastic and/or waterproof tape to prevent internal contamination.
   e) Wash contaminated area with water. Do not abrade patient's skin.

2. Localized skin contamination
   a) Put on examination gloves.
   b) Mark area of contamination with a black marker.
   c) Begin treatment of area with highest contamination first.
   d) Do not injure or abrade skin.

e) Do not spread contamination to other areas of the skin.
f) Wash area with soap and warm water using a gauze pad or surgical sponge. Gently remove horny layer of skin and associated contamination without abrading the skin.
g) Place used gauze pads and/or surgical sponges in a plastic bag and label with appropriate warning label.
h) Store this bag in the nuclear medicine department for subsequent disposal.
i) Repeat Steps f) through h) as necessary.

3. Contaminated wounds
   a) Encourage bleeding when possible.
   b) Irrigate wound with copious amounts of water.
   c) Do not wash skin contamination into the wound.
   d) Decontaminate skin around the wound.
   e) When wound and surrounding skin are decontaminated as much as possible, cover wound with sterile dressing.

4. Eye contamination
   a) For cornea contamination, wash with copious amounts of water.
   b) Sample irrigation fluid at frequent intervals, label samples and save for health physicist.
   c) After decontamination, observe for the onset of conjunctivitis.

5. Contaminated hairy areas
   a) Survey and record results.
   b) Wrap or position the patient to avoid the spread of contamination.
   c) Wash with soap or commercial shampoo (without conditioner) and water and save contaminated fluids in marked and labeled containers.
   d) Dry with clean uncontaminated towel. *Do not shave hair*.
   e) Re-survey.
   f) If contamination persists, repeat washing with mild soap or shampoo (without conditioner) and warm water, until no further reduction in contamination can be affected.

6. Internal decontamination
   a) The type of decontamination treatment is determined by the type(s) of radionuclide(s) involved in the exposure. The objective of therapy is to decrease the absorbed radiation dose and thereby reduce the risk of future biologic effects. Table 1 provides a summary of treatment options for internal contamination by several radionuclides. It is intended by the medical staff in consultation with a professional who is knowledgeable of treating radiologic injuries. A comprehensive discussion of radionuclide-based therapies is provided in NCRP report no. 65 (28) (see References and Resources Section, page 19, item 6).
   b) Questions regarding indications for therapy, onset and type of treatment, and immediate and long-term follow-up should be directed to the hospital radiation safety officer, nuclear medicine physician, and/or radiation oncologist. Additional advice can be obtained by contacting the Radiation Emergency Assistance Center/Training Site (REAC/TS) at 865-576-1005 (telephone) or www.orau.gov/reacts, and/or the Armed Forces Radiobiological Research Institute (AFRRI) at www.afrri.usuhs.mil.

Table 1. Treatment of internal contamination

Element	Primary toxicity	Therapy (dose)
Americium (^{241}Am)	Skeletal deposition Marrow suppression Hepatic deposition	Chelation with DTPA or EDTA (1 g in 150–250 mL D_5W over 1 h)
Cesium (^{134}Ce) Cesium (^{137}Cs)	Renal excretion	Lugol's solution or Prussian Blue (1 g in 100–200 mL H_2O, p.o., t.i.d.)
Iodine (^{131}I)	Thyroid ablation Thyroid cancer	Lugol's solution or potassium iodide (adult: 130 mg, p.o., stat and q.d. × 7–14; child 3–18 y: 65 mg, p.o. stat and q.d. × 7–14)*
Plutonium ($^{238–239}$Pu)	Lung, bone, liver, toxicity	Chelation with DTPA, EDTA (1 g in 150–250 mL D_5W over 1 h)
Radium (^{226}Ra)	Skeletal deposition Marrow suppression	$MgSO_4$ lavage (10% solution) 2 amps of 44.3 mEq in 1000 mL NS, 125 mL/h) Ammonium chloride Calcium aginates $NaHCO_3$
Uranium ($^{238-235}$U)	Renal excretion	Chelation with DTPA, EDTA (1 g in 150–250 mL D_5W over 1 h)

Abbreviations: DTPA = diethylenetriamine pentaacetic acid; EDTA = ethylenediamine tetraacetic acid; amps = ampules; NS = normal saline.

Modified from Jarrett (27).

* See Appendix A, "Pharmaceuticals," regarding dose to children <3 y of age.

APPENDIX H
RADIOGRAPHIC EXAMINATION WITHIN THE DECONTAMINATION AREA

Examination of a decontaminated patient

- A portable X-ray unit can be used within the decontamination area.
- Before entrance into the decontamination area, the X-ray technician will don a surgical scrub suite, shoe covers, cap mask, and gloves.
- No special protection is required for the portable X-ray unit.
- The film cassette should be covered with a protective covering (i.e., plastic trash liner) to prevent contamination.
- If possible, the decontaminated accident victim should be transferred onto a clean stretcher before radiography.
- After the radiographic examination has been completed, the technician's protective clothing (previously described) and the protective covering of the film cassette will be removed and placed in the container labeled "Contaminated Linen and Trash." This is to be performed before exiting the decontamination room.
- The X-ray technicians, the X-ray unit, and the film cassette are to be surveyed with a Geiger-Mueller meter before release from the decontamination area. Additionally, the X-ray unit and film cassette should be wipe-tested for removable contamination.

Examination of the contaminated patient

- A portable X-ray unit is to be used for all radiographic examinations performed within the decontamination area.
- Before entrance into the decontamination area, the X-ray technician will don a surgical scrub suit, shoe covers, cap, mask, and gloves.
- No special protection is required for the portable X-ray unit, providing that it does not come into direct contact with the contaminated patient.
- The X-ray technician should ask the emergency department physician or radiation safety officer present to point out those areas of the accident victim's body that have the highest levels of contamination.
- Extra care should be taken by the X-ray technician when handling a contaminated patient so that the spread of contamination can be minimized.
- After the radiologic examination has been completed, the technician will remove the protective outer clothing (previously described) and the protective covering of the film cassette. Contaminated items will be placed in the container labeled "Contaminated Linen and Trash" before exiting the decontamination area.
- The X-ray technician, the X-ray unit, and the film cassette are to be surveyed with a standard Geiger-Mueller meter before release from the decontamination area. The X-ray unit and film cassette should be wipe-tested for removable contamination.
- Any item found to be contaminated shall not be allowed to be removed from the decontamination area unless authorized by the radiation safety officer. Any decontaminated item will be either removed for storage or decontaminated before release from this area.

APPENDIX I
OPERATING ROOM SAFETY

A victim of a radiation accident who requires either emergency surgery or surgery at a later date who has been exposed only to external radiation requires no special care in the operating room.

For those accident victims who require emergency surgery and who might be externally or internally contaminated with radioactive materials, the staff of the operating room should take the following precautions to minimize the spread of contamination:

- A conventional operating room can be used, provided that there is adequate room to accommodate additional personnel along with the standard operating room staff.
- Everything within the operating room (i.e., operating table, smaller tables, and floor) should be covered with disposable plastic coverings.
- Routine antisepsis measures ensure adequate protection of the operating room staff against contamination.
- Unless otherwise instructed by the radiation safety officer (RSO), there is no danger of contamination to the anesthesia and breathing equipment. Other items (i.e., surgical equipment and instruments, and gloves) should be frequently changed to avoid the spread of contamination. An adequate supply of surgical equipment should be present (i.e., triplicate).
- Equipment should be monitored, surveyed, and wipe-tested by the RSO or his/her designee after use. Contaminated items will be placed in a container and stored in the nuclear medicine department. Areas of gross bodily contamination will be delineated and, if possible, covered with a plastic covering before surgery.
- If an area of bodily contamination is to be surgically incised, it should be washed with normal saline, Betadine, and/or hydrogen peroxide (according to preference of attending surgeon). For persistent contamination, consultation with the RSO might be appropriate regarding the use of diethylenetriaminepentaacetic acid (DTPA) (1 ampule of DTPA per 100 mL of water) or other chelating agent.
- Contaminated tissue removed from the victim should be placed in an appropriately labeled container and stored in the nuclear medicine department or other area of the hospital designated to be appropriate for storage of radio-

active waste. The RSO should be notified of the location and type of stored tissue.

Upon completion of the surgical procedure, the RSO or his/her designee will survey and wipe-test the remaining surgical equipment, surgical garb, and the plastic coverings of the operating room floor to ascertain contamination. Any items that are found to be contaminated will be placed in a container and transported to the nuclear medicine department for storage until adequately decayed. All personnel should be monitored with a standard Geiger-Mueller meter before exiting the operating room suite.

APPENDIX J
SUGGESTED ITEMS: DECONTAMINATION ROOM SUPPLIES

Clothing:	Complete protective clothing for each member of the decontamination team: • Tyvek coveralls • Surgical gloves • Shoe coverings • Surgical masks • Surgical caps
Detection equipment**:	• Personnel dosimeters (pocket ionization type) • Thermoluminiscent dosimeters • Film badges • Geiger-Mueller meters (2) — Ludlum Model #5 with pancake probe (stored in nuclear medicine department)
Decontamination equipment*:	• Cotton applicators • Large plastic bags (collection of clothes) • Adhesive tape and labels • Large towels • Soft scrub brushes • Plastic sheets • General cleansing agents: chlorine bleach, radiac wash (not to be used for patient decontamination), soap • Radiation warning signs • Copy of radiation accident standard protocol • Assorted pens • Specimen bottles (with and without heparin and ethylenediamine tetraacetic acid) • Kitty litter • Emesis basins • Fifty (50) feet of rope • Plastic tarpaulin or other plastic coverings for the floor

APPENDIX K
RELATIVE RISK FROM VARIOUS RADIATION DOSE RATES DURING EMERGENCY DEPARTMENT PATIENT CARE ACTIVITIES INVOLVING CONTAMINATED PATIENTS

If dose rate at 30 cm (12 in) is # mR/h*	Then the resulting total dose to the emergency department worker from patient care activities is likely to be comparable to:
1	Insignificant (a plane ride coast to coast)
10	Low (2 mo of natural background radiation)
100	Moderate (1 y of natural background radiation)
1000	High (the annual dose limit for radiation workers)
10,000	Very high (the per-flight limit for National Aeronautics and Space Administration astronauts)

The radiation safety office (RSO) or other expert should consider obtaining informed consent before allowing emergency department staff to work in high or very high dose rates.

Radiation badges should be issued for all workers directly in moderate to very high dose rates.

The RSO or other expert should consider reclassifying the dose rate each hour and rotating staff if indicated.

See also Environmental Protection Agency guidelines for emergency responders in the event of extremely high dose rates.

* Assumes a 5-h exposure time.