Current Concepts

Major Radiation Exposure — What to Expect and How to Respond

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UNCONTROLLED, large-scale exposure to radiation has been caused by the detonation of atomic bombs over Japan, fallout from atomic-bomb tests, nuclear-reactor accidents, and the release of material from radiotherapy devices. In the wake of the September 11, 2001, terrorist attacks, it is important to understand the potential scenarios of major radiation exposure, the basic principles of such exposure, and how medical personnel should respond.[1-4] Management of radiation exposure is difficult, in part, because of misinformation on the part of the exposed persons, family members, and medical staff about the effects of exposure.

In some respects, major radiation exposure due to a terrorist attack should be easier to manage than chemical or biologic attacks. An important resource is the tens of thousands of persons who deal with radiation daily at hospitals, universities, military units, national laboratories, and government agencies. Radioactive contamination can be quickly detected with Geiger counters or dose-rate meters, which are available in more than 3000 hospitals and are often carried by emergency personnel. In addition, the immediate clinical effects of large doses of radiation are well known and can be assessed with the use of simple laboratory tests such as blood counts. With rapid assessment of the location and magnitude of the problem, management of the crisis can be relatively definitive, and the public can be informed promptly and accurately.

POSSIBLE SCENARIOS

To date, the assumption is that terrorists would use only one type of agent at a time. A combination of agents could be used, but there is not likely to be synergism between radiation and other agents. Most chemical agents have immediate effects that would need to be managed before the subsequent effects of radiation could be addressed. Exposure to radiation from sources other than a nuclear weapon should be relatively manageable, since it is very difficult to expose many people to large doses of radiation and small doses do not affect health for many years.

Dispersal of Radioactive Substances without the Use of Explosives

Minimally radioactive sources might be used to cause fear or panic. These sources include "exempt" low-level radioactive sources (e.g., smoke detectors), radiopharmaceutical agents used in nuclear medicine, and isotopes used in research. No immediate effects on health would be expected from exposure to these sources, and the probability of long-term effects would be very low.

Highly radioactive sources are also available, such as cobalt-60 and cesium-137, previously used in radiotherapy machines, and cesium-137 and iridium-192, used in industrial radiographic devices. Because of the large amount of radioactivity present in these devices and the penetrating nature of the radiation, their transport would be relatively easy to detect at checkpoints. The sources are usually metallic, although a few devices contain powder in a capsule.[5] If the source is metallic, there will be exposure to radiation but no contamination. Serious exposure will probably involve only a few persons. Those who are very close to these highly radioactive sources or who handle them may have local skin injuries and will be at risk for the acute radiation syndrome, which requires medical evaluation and possibly hospitalization.[6-8]

Dispersal of Radioactive Substances with the Use of Conventional Explosives

The use of explosives to disperse radioactive substances is of greater concern, because explosives would spread the substances to larger numbers of people and because there might be associated traumatic injuries. The purpose of including radioactive material with the explosives would be to cause additional fear and panic. The radioactive material would probably be in solid or powdered form. The extent of its dispersion would depend on the physical form of the source, the explosives, and the atmospheric conditions. A major health hazard would probably be restricted to an area of a few city blocks. The goal of the response would be to monitor and control the contaminated area.

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Attacks on Nuclear Reactors

The possibility of terrorist attacks on nuclear power plants has been mentioned in the media.[9] At all commercial nuclear power plants in the United States, the reactor core is encased in a thick stainless-steel vessel within a concrete containment building. If an accident occurs, the reactor is designed to slow down and stop the reaction. The coolant system of a reactor does contain some radioactivity, which could be released if the coolant system were damaged. Released substances would probably include radioactive iodine and noble gases. An atmospheric plume of radioactive substances released through a breach in the reactor core could have immediate health effects nearby. Moreover, the release of large amounts of radioactive iodine could have long-term effects (e.g., thyroid cancer in children) at great distances. Many nuclear-engineering departments in universities have small experimental reactors in densely populated urban areas, with minimal security. These reactors contain much smaller amounts of radioactive material, but they may be inviting targets for terrorist attacks. In addition, "spent" but still radioactive fuel rods are often stored in less secure facilities. It would be very difficult, however, to expose a large population to radiation from these solid sources.

Detonation of Nuclear Weapons

A nuclear weapon requires more technical expertise and more money to develop and use than does either a biologic or a chemical weapon, and the use of a nuclear weapon by terrorists is therefore considered to be less likely.[2,10-12] Nevertheless, it is possible to construct a low-yield (<10 kt) nuclear device. A stolen compact nuclear weapon could have a higher yield. For reference, the bomb used at Hiroshima had an approximate yield of 13 kt. However, even a nuclear-weapon detonation that fizzled could have a substantial explosive impact, even though the yield might only be on the order of 0.01 kt.

The destructive effects of nuclear weapons are due to the air blast as well as to thermal radiation. An increase in pressure of 1 psi will break glass. At 12 psi, the predicted fatality rate among persons close to windows is 50 percent. The fireball will cause flash and flame burns as well as burns in an ensuing firestorm. Looking at the fireball even from several miles away can cause temporary or permanent blindness. Ionizing radiation is released as an intense pulse during the first minute (initial radiation) and as fission and activation products after the first minute (residual radiation). A ground burst injects a large amount of radioactive soil and other materials into the atmosphere, causing radioactive fallout that may extend over an area of hundreds of miles. Unless persons are protected from exposure in a shelter or are evacuated, the fallout can be lethal at greater ranges than either the blast or the fireball. A summary of approximate effects is shown in Table 1.

BASIC PRINCIPLES

Physical Principles

There are several common forms of ionizing radiation. Gamma rays and x-rays easily penetrate body tissues and deposit their energy deep in the body. Alpha-emitting radionuclides are hazardous only when they are inhaled, ingested, or deposited in an open wound, because alpha particles penetrate less than 0.1 mm in tissue. Beta particles (electrons) can penetrate to a depth of a few centimeters.

The radiation dose of interest for assessing health effects is the dose absorbed by specific tissues, measured in rads. The international unit of measurement for the absorbed dose, the gray (Gy), is equal to 100 rad. Since various forms of radiation (e.g., gamma rays and alpha particles) have different biologic effects at the same absorbed dose, the effective dose should be used for comparisons. The conventional unit of measurement for the effective dose is the rem. The international unit, the sievert, is equal to 100 rem. For practical purposes, a gray and a sievert are essentially equal when one is dealing with gamma and beta rays.

Important factors in minimizing the effects of radiation are time, distance, and shielding. Since the absorbed dose is directly proportional to time, only the minimal necessary amount of time should be spent in the vicinity of a radioactive source. The absorbed dose decreases rapidly with the square of the distance from the source. Tripling the distance from

TABLE 1. APPROXIMATE DISTANCE FROM THE DETONATION SITE AT WHICH A 50 PERCENT FATALITY RATE MIGHT BE EXPECTED, ACCORDING TO THE SIZE OF A NUCLEAR WEAPON.*

YIELD	SHOCK WAVE	THERMAL RADIATION	IONIZING RADIATION	
			INITIAL	RESIDUAL†
		meters		
0.01 kt	60	60	250	1270
0.1 kt	130	200	460	2750
1 kt	275	610	790	5500
10 kt‡	590	1800	1200	9600

*Data are from the National Council on Radiation Protection and Measurements.[2]

†Data are for residual radiation (mostly fallout) in the first hour.

‡At yields exceeding 10 kt, the lethal range of the fireball extends several times farther than the lethal range of either the blast or the initial radiation.

the source decreases the dose rate to one ninth. Shielding with lead can be used as protection from small radioactive sources. Staying indoors may be necessary for protection from a radioactive atmospheric plume.

Radioactivity decays with time. Some radionuclides (e.g., iodines) are short-lived, whereas others (e.g., cesium, strontium, and cobalt) have physical half-lives of many years. The cumulative dose depends not only on the dose rate measured at a point in time, but also on the duration of exposure and the rate of decay. The decay rate may affect some management decisions, such as whether to decontaminate the affected area or simply to let the radionuclide decay.

Biologic Principles

At high doses of radiation, some parenchymal cells die, but the clinical effect may be insignificant if the cells are not critical for survival. However, if a large number of cells are killed or if those that die are essential for survival, clinical symptoms develop.[13-15] In general, rapidly dividing cells (e.g., intestinal-mucosa and bone marrow cells) are most vulnerable to radiation. At doses of less than 1.0 Gy, the damage is generally not severe, and the majority of cells survive, but they may be susceptible to subsequent malignant transformation. In this article, we do not review the long-term effects of radiation exposure (carcinogenesis), except to note that the probability of radiation-induced cancer is dose-related. Leukemia can develop as early as two years after exposure, whereas radiation-induced solid tumors may develop after a period of 5 to 10 years or even several decades.[16-19]

TYPES OF RADIATION EXPOSURE

Radiation accidents can result in localized or whole-body exposure and in internal or external deposition of radioactive materials (contamination). The clinical manifestations of exposure to radiation depend on the extent of penetration and the absorbed dose in various tissues. Recognition of acute radiation injuries is based on the history and clinical findings.[1,3,20-23] Most radiation injuries do not constitute a medical emergency; management consists of the treatment of symptoms and supportive care.

Localized Exposure

Localized, deep exposure to radiation is caused by direct handling of highly radioactive sources. The patient often survives even if the absorbed doses are very high. Because the dose rate drops rapidly as the distance from the radioactive sources increases, systemic manifestations are not as severe as the local injury.

The signs of a radiation burn are similar to those of a thermal burn: erythema and desquamation or blistering. However, the signs of a radiation burn appear after a period of days (Table 2). Vascular insufficiency can develop several months or years later,

ABSORBED DOSE	CHANGE
3–4 Gy	Epilation in 2–3 wk
10–15 Gy	Threshold for erythema; appears 18–20 days after exposure at lower doses; may appear within a few hours at higher doses
20 Gy	Moist desquamation, possible ulceration
25 Gy	Ulceration with slow healing
30–50 Gy	Blistering, necrosis at 3 wk
100 Gy	Blistering, necrosis at 1–2 wk

TABLE 2. SKIN CHANGES AFTER A SINGLE ACUTE, LOCALIZED EXPOSURE.*

*Data are from Gusev et al.[1]

causing ulceration or necrosis of tissues that had previously healed. Treatment of localized radiation injuries usually involves prophylaxis against infection, control of pain, and vasodilator therapy; in some cases, plastic surgery, grafting, or amputation is required. The extent of penetration of the radiation is an important factor in the outcome of local injury. With heavy radioactive fallout, beta rays cause superficial skin burns, particularly on portions of the body not covered by clothing.

Whole-Body Exposure

Abnormalities in the most susceptible tissues are manifested in the first days and weeks after whole-body radiation exposure. A large, single exposure to penetrating radiation can result in various forms of the acute radiation syndrome (Table 3). Within the first 12 hours after exposure, there is a prodromal phase, consisting of nausea and vomiting, which lasts for up to 48 hours.

At doses exceeding 30 Gy of whole-body, penetrating radiation, cardiovascular and central nervous system damage occurs, primarily as a result of hypotension and cerebral edema. There is almost immediate nausea, vomiting, prostration, hypotension, ataxia, and convulsions. Death usually occurs within several days.

Acute, whole-body doses of approximately 10 to 30 Gy cause a gastrointestinal syndrome, primarily as a result of the death of intestinal mucosal stem cells. This syndrome is characterized by the rapid onset of nausea, vomiting, and diarrhea, which is followed by a latent period of approximately one week and then by recurrent gastrointestinal symptoms, sepsis, electrolyte imbalance, and ultimately death.

A clinically significant hematopoietic syndrome occurs after whole-body doses of 2 Gy or higher as

TABLE 3. DOSE–EFFECT RELATION AFTER ACUTE WHOLE-BODY RADIATION FROM GAMMA RAYS OR X-RAYS.*

WHOLE-BODY ABSORBED DOSE	EFFECT
0.05 Gy	No symptoms
0.15 Gy	No symptoms, but possible chromosomal aberrations in cultured peripheral-blood lymphocytes
0.5 Gy	No symptoms (minor decreases in white-cell and platelet counts in a few persons)
1 Gy	Nausea and vomiting in approximately 10 percent of patients within 48 hr after exposure
2 Gy	Nausea and vomiting in approximately 50% of persons within 24 hr, with marked decreases in white-cell and platelet counts
4 Gy	Nausea and vomiting in 90% of persons within 12 hr, and diarrhea in 10% within 8 hr; 50% mortality in the absence of medical treatment
6 Gy	100% mortality within 30 days due to bone marrow failure in the absence of medical treatment
10 Gy	Approximate dose that is survivable with the best medical therapy available
>10–30 Gy	Nausea and vomiting in all persons in less than 5 min; severe gastrointestinal damage; death likely in 2 to 3 wk in the absence of treatment
>30 Gy	Cardiovascular collapse and central nervous system damage, with death in 24 to 72 hr

*Data are from Gusev et al.[1]

a result of bone marrow depression. After the prodromal symptoms, there is a latent period of two to three weeks during which the patient may feel well. A reduction in the lymphocyte count can occur within 48 hours after exposure, and the magnitude of the reduction is a useful indicator of the radiation dose (Table 4).[24] Maximal bone marrow depression with leukopenia and thrombocytopenia occurs several weeks after exposure, when hemorrhage and infection can be major problems. If the bone marrow is not completely eradicated, a recovery phase ensues, which may be enhanced through use of hematopoietic growth factors.[25-27] If there is extensive skin injury, the damaged functions of the skin may interact with other organ damage. Some authors have referred to this as the "cutaneous syndrome."

A number of drugs that provide protection against radiation have been suggested for use in terrorist attacks. To be effective, most of these drugs need to be given before exposure. Amifostine is approved by the Food and Drug Administration (FDA) for some patients undergoing radiation therapy, but it has serious side effects, including hypotension, which severely limit its use in emergency personnel who must engage in physically demanding activities. Andro-

stenediol has recently been proposed as a prophylactic drug, but it has been evaluated only in animals. Moreover, androstenediol boosts the immune system, which is required only if the radiation dose approaches the lethal level. Bone marrow transplantation, which has been performed in patients with whole-body doses in excess of 12 Gy, has not been helpful. Experience with accidental exposure has shown that, even if the hematopoietic syndrome is successfully treated, death invariably follows from radiation pneumonitis, denudation of the alimentary tract, and hepatic and renal dysfunction.[28,29]

Internal Contamination

Internal contamination can occur from the dispersal of powdered, liquid, or gaseous radioactive material. The material may enter the body by inhalation or ingestion, through intact skin, or through wounds or burns. Effective treatment requires knowledge of both the radionuclide and the chemical form. Unless treatment is instituted quickly, its effectiveness will be limited. There are several general approaches to the treatment of internal contamination, including reduction of absorption, dilution, blockage, displacement by nonradioactive materials, mobilization as a means of elimination from tissue, and chelation (Table 5).[30]

In the event of the detonation of a nuclear weapon or the release of radioactive material from a nuclear reactor, the most likely treatment of internal contamination would be the use of potassium iodide or iodate to prevent radioiodine from accumulating in the thyroid.[31] The recommended daily dose of potassium iodide is 130 mg for adults, 65 mg for children 3 to 18 years old, 32 mg for children 1 month to up to 3 years old, and 16 mg for infants less than 1 month old. Potassium iodide must be taken shortly before exposure or within several hours after exposure to be effective. Both the Nuclear Regulatory Commission and the FDA have approved the use of potassium iodide in emergencies. Potassium iodide is widely available through the mail and the Internet. Too high a dose will result in iodism, but the risk of serious side effects with the recommended dose is extremely small. Chelating agents (calcium or zinc diethylenetriamine pentaacetic acid) are investigational drugs and are useful only if there is direct dispersal of plutonium or americium. Such agents are not very useful for the treatment of contamination with other radionuclides, and they are not useful after the detonation of a nuclear weapon.

External Contamination

Radioactive contamination of clothing and exposed skin does not constitute a medical emergency. Management of such cases of exposure is simply a matter of removing and controlling the spread of ra-

TABLE 4. PROGNOSIS ACCORDING TO THE LYMPHOCYTE COUNT WITHIN THE FIRST 48 HOURS AFTER ACUTE EXPOSURE TO PENETRATING, WHOLE-BODY RADIATION.

MINIMAL LYMPHOCYTE COUNT	APPROXIMATE ABSORBED DOSE	EXTENT OF INJURY	PROGNOSIS
per mm³	Gy		
1500–3000 (normal range)	0–0.4	No clinically significant injury	Excellent
1000–1499	0.5–1.9	Clinically significant but probably nonlethal	Good
500–999	2.0–3.9	Severe	Fair
100–499	4.0–7.9	Very severe	Poor
<100	≥8.0	Most severe	High incidence of death even with hematopoietic stimulation

TABLE 5. SPECIFIC THERAPY FOR INTERNAL CONTAMINATION.*

RADIONUCLIDE	THERAPEUTIC APPROACH
Tritium	Dilution (force fluids)
Iodine-125 or iodine-131	Blockage (SSKI or potassium iodide), mobilization (antithyroid drugs)
Cesium-134 or cesium-137	Reduction of gastrointestinal absorption (Prussian blue)
Strontium-89 or strontium-90	Reduction of absorption (aluminum phosphate gel antacids), blockage (strontium lactate), displacement (oral phosphate), mobilization (ammonium chloride or parathyroid extract)
Plutonium and other transuranic elements	Chelation with zinc or calcium diethylenetri-amine pentaacetic acid (investigational agents)
Unknown	Reduction of absorption (emetics, lavage, charcoal, or laxatives) in cases of ingestion

*Data are from Gusev et al.[1] SSKI denotes saturated solution of potassium iodide.

dioactive materials. Removal of clothing usually results in the elimination of 90 percent of the contamination. Even extensive surface contamination is not likely to result in overexposure on the part of medical personnel. When workers at Chernobyl who were in the reactor area at the time of the nuclear accident were decontaminated, the medical personnel at the site received less than 10 mGy of radiation. Medical personnel should wear protective clothing and gloves in conformity with universal precautions. Respirators are not required at the hospital but should be worn by rescue personnel entering highly contaminated areas.

If the patient has surface contamination and no physical injuries, decontamination can be effectively performed with the use of water and detergent. If there is substantial physical trauma, or if there are life-threatening injuries in addition to surface contamination, the patient should be stabilized physiologically before decontamination is performed. The skin is an important barrier and should not be abraded during decontamination. All contaminated materials should be placed in large, labeled plastic bags, with proper disposal of the bags.

Contaminated Burns and Wounds

If a patient with surface contamination has a wound that is not contaminated, it should be covered until the radioactive material has been removed. A wound that contains radioactivity should be rinsed with saline and treated according to conventional aseptic techniques. Excision is usually reserved for long-lived radionuclides (especially alpha-emitting radionuclides). If the patient has received a whole-body dose of radiation that exceeds 1 Gy, the wound should be closed as soon as possible so that it does not become a portal for lethal infection. Contaminated burns should be gently rinsed and then treated in the conventional manner. Radioactive material often comes off with the exudate or eschar.

GENERAL MANAGEMENT

Management of events involving the dispersal of radioactive materials can be divided into three phases: preparation, management during the crisis, and management of its consequences. The preparation phase includes emergency planning, clarification of command and control issues, specification of organiza-

tional responsibility, development of notification criteria and communications systems, assessment of the type and quantity of equipment required, and specification of levels of protective actions that will be taken under certain circumstances.[32-35] At all levels, the involvement of health care facilities is crucial.[36] Most metropolitan-area hospitals are still not adequately prepared.

Training can be divided into training for the public and training for those directly dealing with radiation or contamination. The specific components of training depend on the potential level of radiation exposure and on the task at hand. Training for emergency personnel should include information about the nature of radiation, levels of risk, methods of protection, and priorities for management. Training must also include mock exercises with an emphasis on large-scale disasters and terrorist events. In addition to training, there must be an assessment of the availability of beta–gamma survey instruments and dose-rate meters, potassium iodide, and reference materials. There should also be a program covering the measurement and recording of doses, use and maintenance of dosimeters, and use of exposure information.

In the event of a terrorist incident, the Federal Bureau of Investigation is the lead federal agency in the United States during crisis management[37]; in other countries, an appropriate resource should be identified. Crisis management refers to activities undertaken to ensure that there is no further threat and to establish control over the site of the attack as a crime scene. Consequence management refers to prevention or limitation of further damage, protection of the public, decontamination, and disposal of radioactive material. During consequence management, the Federal Emergency Management Agency becomes the lead federal agency in the United States.[38] In both phases, a federal joint operating center is established to work with other federal agencies.

Intervention refers to actions taken to reduce the exposure to and dose of radiation. These actions may include controlling access to the site, directing people to stay indoors or evacuating them, removing contaminated clothing, providing respiratory protection, administering potassium iodide, restricting certain foods, and decontaminating property. Guidelines have been developed that specify which actions to take if a particular dose level is likely to be reached.[39-42]

According to international recommendations, people should stay indoors for up to two days if a dose of 1 rem is likely to be reached, with evacuation for up to one week if the likely dose is 5 rem or higher.[41] Temporary relocation is recommended at a likely dose of 3 rem in the first month or 1 rem in a subsequent month. Permanent resettlement is recommended if the lifetime dose is expected to be 100

rem. The administration of potassium iodide is recommended if the estimated dose to the thyroid is 100 mGy or higher. There are similar criteria for the restriction of food and milk if the activity of radionuclides exceeds a certain level. Experience with prior events has provided the basis for the establishment of exposure limits and levels of radioactivity in food and water that are thought to be safe. (Safe levels are usually defined as those associated with a risk of death of 10^{-4} to 10^{-6} annually.)

With regard to the actions of emergency personnel, the occupational dose limit (5 rem per year) does not apply.[43] According to the guidelines of the Environmental Protection Agency, the dose limit for persons providing emergency services other than lifesaving activities is 5 rem per event; for lifesaving activities, the dose can exceed 25 rem per event. The North Atlantic Treaty Organization uses 150 rem as the limit in a disaster. The cumulative dose is difficult to measure in emergency personnel, and dose-rate criteria are usually used. At a dose of 0.1 mGy per hour, emergency personnel may enter an area to perform critical, time-sensitive tasks.[2] At a dose of 0.1 Gy per hour, exposure may be life-threatening, and emergency personnel should return to their control point to await instructions from a radiation expert on how to proceed.

Early Management

Initial management consists of on-the-scene triage and transportation of victims to emergency rooms for treatment. The principles of handling hazardous materials, which are based on the assumption that the toxic environment is relatively contained, provide for maximal protection of a few workers while they are rescuing a small number of patients. This approach will not be practical if there are large numbers of casualties and little or no notice. Persons with life-threatening injuries should be handled as if they were contaminated and taken to a local hospital. Those who are uninjured or have minor injuries should be evacuated (upwind if possible) and then evaluated for possible contamination. The usual procedure for on-the-scene decontamination is not adequate if there are large numbers of patients. In the event of a chemical and biologic event, the local health care facility is primarily responsible for decontamination, but this approach is not necessary and may even be inadvisable in the case of widespread dispersal of radioactive materials.

Ambulance staff should wear gowns and gloves and appropriately dispose of the victims' outer clothing. The hospital should be informed of the imminent arrival of seriously injured and possibly contaminated patients. Contaminated persons who are uninjured or have only minor injuries should be taken to a designated center for registration, decontamination (re-

moval of clothing and showering), and treatment of minor injuries. Persons who report nausea, vomiting, or diarrhea should be referred to a hospital for evaluation of whole-body exposure. If possible, the evaluation should be performed at a facility other than the one providing care for contaminated patients who have life-threatening traumatic injuries.

In the emergency room, patients should receive care in an area where access is controlled (with the use of ropes and signs), and exits should be monitored so that contamination is not spread. Security is necessary to prevent unauthorized access. The medical staff should adopt universal precautions. Patients can be moved with minimal spread of contamination by wrapping them in cloth sheets. Containment of wastewater is probably not possible, and its release can be justified in almost all situations.

Psychosocial Effects

Psychosocial issues would be very important in a terrorist attack involving the release of radioactive material.[44] The possibility of exposure to radiation elicits the fear of an unfamiliar hazard that can cause hidden and irreversible damage. Common acute stress reactions include insomnia, impaired concentration, and even social withdrawal. Since several psychological symptoms mimic those of radiation exposure (nausea, vomiting, and rash), it is important to have effective triage procedures in place. It has been estimated that after the detonation of a nuclear weapon, about 75 percent of persons would have some psychological symptoms.[11]

Experience with acts of terrorism suggests that there could be very high rates of post-traumatic stress disorder after a major radiation exposure, especially among family members and colleagues of victims.[45,46] The long-term risks after radiation exposure also pose a threat that can cause a permanent state of anxiety. Persons who have been exposed to radiation may suffer from both stigma and chronic stress. Stress can occur even in the absence of actual exposure to radiation. Groups at high risk for psychological effects include children, pregnant women, mothers of young children, emergency workers, cleanup workers, and persons with a history of mental illness. The guiding principle in dealing with psychosocial effects is prevention. The goal should be to maintain or restore trust through openness, communication, and decisions that are rational and participatory.

RESOURCES

For questions about radiation exposure and injuries, the U.S. Department of Energy can be contacted 24 hours a day at the Radiation Emergency Assistance Center/Training Site (REAC/TS) in Oak Ridge, Tennessee (telephone number, 865-576-1005;

interactive Web site, http://www.orau.gov/reacts). For information about the training of physicians, REAC/TS can be contacted at 865-576-3131. The *Medical Management of Radiological Casualties Handbook* is available online at http://www.afrri.usuhs. mil. The Chemical/Biological Hotline of the National Response Center is 800-424-8802.

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