The insoluble radionuclides may affect the lower gastrointestinal tract. Intact skin is normally an effective barrier to most radionuclides. Penetration through the skin usually takes place when wounds or burns have compromised the skin barrier. Therefore, any skin erosion should be cleaned and decontaminated promptly.

Absorbed radioactive materials travel throughout the body. Liver, kidney, adipose tissue, thyroid, and bone and bone marrow tend to bind and retain radioactive material more than other tissues do. Medical treatment thus includes the prevention of absorption, the reduction of incorporation, and the enhancement of elimination (see below).

Localized exposure refers to close contact between a highly radioactive source and a part of the body, with consequent discrete damage to the skin and deeper tissues that resembles a thermal burn. Later signs include epilation, erythema, moist desquamation, ulceration, blistering, and necrosis in proportion to exposure. Alopecia, transient or permanent, is dose related and starts at cutaneous doses of >3 Gy. Overt tissue damage can take weeks or even months to develop; the healing process can also be very slow, lasting for months. Long-term cutaneous changes, including keratosis, fibrosis, and telangiectasis, may appear years after the exposure. Treatment is based on analgesia and infection prophylaxis. Nevertheless, severe burns often require grafting or even amputation. Long-term radiation effects are characterized by cell loss, cell death, and tissue atrophy.

RADIOLOGIC DISPERSAL EVENTS

Radiologic dispersal incidents are generally of two types, resulting from small, usually localized sources or from wide dispersals over large areas. The methods that could be utilized to formulate an attack using dispersal of radiation are incredibly diverse. Radioactive materials can take the form of solid state, aerosol, gas, or liquid. They can be put into food or water, released from vehicles, or spread by explosion. The principal route of exposure is usually direct contact between the victim's skin and the radioactive particles, although internal contamination can occur if the material is inhaled or ingested. The radiation field is also a potential source of whole-body exposure. The psychosocial effects that accompany such an event are significant and are beyond the scope of this chapter. A list of radioactive materials, including information on their major properties and medical treatment, is given in **Table 263e-1**.

In a localized event, the amount and spread of the radioactive materials are usually limited and can be treated like a spill of hazardous material. Protective clothing prevents or minimizes the contamination of emergency responders.

The use of explosives coupled with a large amount of radioactive materials can result in wide dispersion of radiation, which is of far greater concern. Other potential sources of radiation are nuclear reactors, spent nuclear fuel, and transport vehicles. Less probable but still possible is the use of a large source of penetrating radiation without explosion. It is expected that most exposures would be low-level and that the principal health and psychosocial effects would be similar to those in the former scenario but on a larger scale. Whenever an explosion is involved, conventional lifesaving treatment should be given first priority. Only then should decontamination and specific treatment be given for the radiation exposure.

Silent exposure represents a scenario in which a powerful radiologic source, often called a *radiologic exposure device*, could be hidden in a crowded place and spread radioactive materials without being recognized or reported. Recognition of the event and the source of exposure might take a long time. A major clue in this situation is the appearance of unusual clinical manifestations in many individuals; such manifestations are often nonspecific and include symptoms of acute radiation sickness (see "Acute Radiation Syndrome," below) such as headache, fatigue, malaise, and opportunistic infections. Gastrointestinal phenomena such as diarrhea, nausea, vomiting, and anorexia may occur. Dermatologic symptoms (e.g., burns, ulceration, and epilation) and hematopoietic manifestations (e.g., bleeding tendency, thrombocytopenia, purpura, lymphopenia, and neutropenia) are also possible and are dose-related. Careful epidemiologic studies may be necessary to identify the source of such exposure.

NUCLEAR WEAPONS

The most likely scenario in a nuclear terror attack is the detonation of a single low-yield device. The estimated yield of such a device is anywhere between 0.01 and 10 kilotons of 2,4,6-trinitrotoluene (TNT). The expected effects of such an explosion are a combination of several components: ground shock, air blast, thermal radiation, initial nuclear radiation, crater formation, and radioactive fallout.

A nuclear detonation, like a conventional explosion, produces a shock wave that can further damage structures and cause many casualties. In addition, the detonation can produce an extremely hot fireball that can ignite materials and cause severe burns. The detonation releases an intense pulse of ionizing radiation consisting mainly of gamma rays and neutrons. The radiation produced in the first minute is termed *initial radiation*, whereas the ongoing radiation due to fallout is termed *residual radiation*. Both types of radiation can cause acute radiation sickness, and winds can carry fallout and contaminate large areas. The $LD_{50/30}$ (i.e., the dose that causes a 50% mortality rate at 30 days) is ~4 Gy for whole-body exposure without medical support; with medical support, the $LD_{50/30}$ ranges between 8 and 10 Gy. On top of its immediate effects, a massive blast forms a crater in the soil and usually produces ground shock that compounds the physical damage and the number of casualties. Inhalation of large amounts of radioactive dust causes pneumonitis that can lead to pulmonary fibrosis. Use of a mask covering the mouth and nose can result in effective prevention. The intense flash of infrared and visible light can cause either temporary or permanent blindness. Cataracts can develop months to years later among survivors.

ACUTE RADIATION SYNDROME

Acute radiation syndrome (ARS) refers to multisystem symptomatology resulting hours to weeks after radiation exposure. As discussed earlier, cell sensitivity to radiation damage increases as the cell replication rate increases and as cell differentiation decreases. Bone marrow and mucosal surfaces of the gastrointestinal tract, which have vast mitotic activity, are significantly more sensitive to radiation than are slowly dividing tissues such as bones and muscles. After exposure of all or most of the human body to ionizing radiation, ARS can develop. The clinical manifestations of ARS reflect the dose and type of radiation as well as the parts of the body exposed.

ARS manifests as three major groups of signs and symptoms: hematopoietic, gastrointestinal, and neurovascular. In addition, ARS exists in four stages: prodrome, latent phase, clinical illness, and recovery or death. The higher the radiation doses, the shorter and more severe each stage. The prodrome appears within minutes to 4 days after exposure, lasts from a few hours to a few days, and can include nausea, vomiting, anorexia, and diarrhea. At the end of the prodrome, ARS progresses to the latent phase. Minimal or no symptoms are present during the latent phase, which commonly lasts up to 2.5 weeks but can last up to 6 weeks. The duration depends on the radiation dose, the prior health of the patient, and coexisting illness or injury. After the latent phase, the exposed person manifests illness that may end in recovery or lead to death.

With exposure to low doses of <1 Gy, ARS is generally mild. At this dose, symptoms can be minimal or nonexistent, even if the entire body is exposed to penetrating radiation. The main feature of the clinical picture is transient depression of bone marrow (lymphopenia) that lasts up to 2–3 weeks and then improves.

ARS is significantly more acute and severe with exposure to very high radiation doses (>30 Gy). At these doses, the prodrome appears in minutes and is followed by 5–6 hours of latency before cardiovascular collapse occurs secondary to irreversible damage to the microcirculation.

Exposure to intermediate radiation doses may result in variable ARS courses. The type and dose of radiation and the part of the body exposed determine not only the timing of the different stages of ARS but also the dominant clinical picture. At low radiation doses of 0.7–4 Gy, hematopoietic depression due to bone marrow suppression is the main constituent of illness. The patient may develop infection and bleeding secondary to low leukocyte and platelet counts, respectively. The bone marrow eventually recovers in almost all patients if