263e Radiation Terrorism

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The threat of a terror attack employing nuclear or radiation-related devices is unequivocal in the twenty-first century. Such an attack would certainly have the potential to cause unique and devastating medical and psychological effects that would require prompt action by members of the medical community. This chapter outlines the most probable scenarios for an attack involving radiation as well as the medical principles for handling such threats.

Potential terrorist incidents with radiologic consequences may be considered in two major categories. The first is the use of radiologic dispersal devices. Such devices disseminate radioactive material purposefully and without nuclear detonation. An attack with a goal of radiologic dispersal could take place through use of conventional explosives with incorporated radionuclides ("dirty bombs"), one or more fixed nuclear facilities, or nuclear-powered surface vessels or submarines. Other means could include detonation of malfunctioning nuclear weapons with no nuclear yield (nuclear "duds") and installation of radionuclides in food or water. The second and less probable scenario is the actual use of nuclear weapons. Each scenario poses its own specific medical threats, including "conventional" blast or thermal injury, introduction to a radiation field, and exposure to either external or internal contamination from a radioactive explosion.

TYPES OF RADIOISOTOPIC RADIATION

Atomic isotopes with uneven numbers of protons and/or neutrons are typically unstable; such isotopes discharge particles or energy to matter as they move to stability, a process that is defined as *radiation*. Mass-containing particles, including alpha particles, electrons, and/or neutrons, may be transferred during this process (alpha radiation, beta radiation, and neutron radiation, respectively); alternatively, the transfer may consist only of energy in the form of a gamma ray. *Alpha* (α) *radiation* consists of heavy, positively charged particles, each of which contains two protons and two neutrons. Alpha particles usually are emitted from isotopes that have an atomic number of ≥82, such as uranium and plutonium. Due to their large size, alpha particles have limited penetrating power. Fine obstacles such as cloth and human skin usually can stop these particles from penetrating into the body. Thus they represent a small risk from external exposure. If they are somehow internalized, however, alpha particles can cause significant damage to human cells that are in their immediate proximity.

Beta (β) *radiation* consists of electrons, which are small, light, negatively charged particles (about 1/2000 the mass of a neutron or proton). Electrons can travel only a short, finite distance in tissue, with the precise distance depending on their energy. Exposure to beta particles is common in many radiation accidents. Radioactive iodine released in nuclear plant accidents is the best-known form of beta radiation. Plastic layers and clothing can stop most beta particles, and their penetration is generally measured at a few millimeters. A large quantum of energy delivered via beta particles to the basal stratum of the skin can cause a burn that is similar to a thermal burn and is treated as such.

Gamma (γ) *rays* and *x-rays* (both photons) are similar. Gamma rays are uncharged electromagnetic radiation discharged from a nucleus as a wave of energy. X-rays are the product of abrupt mechanical deceleration of electrons striking a heavy target such as tungsten. Although they are generated by different sources, gamma rays and x-rays have similar properties; that is, they have no charge and no mass, just energy. They travel easily through matter and thus are sometimes referred to as *penetrating radiation*. Gamma rays and x-rays are the principal types of radiation that cause dangerous total-body exposure. Gamma rays and x-rays of the same energy will cause the same biologic effects, and these effects will require the same treatment.

Neutron (η) *particles* are heavy and uncharged and are often emitted during nuclear detonation. They possess a wide energy range; their ability to penetrate tissues is variable, depending on their energy. They are less likely to be present in most scenarios of radiation bioterrorism than are the other forms of radiation discussed above.

Radiation interactions with atoms can result in ionization and the formation of free radicals that damage tissue by disrupting chemical bonds and molecular structures in the cell, including DNA. Protons, electrons, and gamma rays cause cellular damage through ionization of DNA. Depending on energy and other factors, some fraction of this damage will be caused by a direct strike to the DNA molecule (*direct ionization*). The remainder will be caused by ionization of water molecules to create free radicals that, in turn, damage DNA (*indirect ionization*). Ionization of DNA resulting from neutrons is exclusively indirect. Radiation damage can lead to cell death; the cells that recover may be mutated and at higher risk for subsequent cancer evolution. Cell sensitivity increases as the replication rate increases and cell differentiation decreases.

The commonly used units of radiation are the rad and the gray (Gy). The rad (*radiation absorbed dose*) is energy deposited within living matter and is equal to 100 ergs/g of tissue. The traditional rad has been replaced by the Système Internationale (SI) unit of the gray; 100 rad = 1 Gy, while 1 Gy is equal to 1 joule/kg. The sievert (Sv) is the SI unit that refers to the equivalent radiation dose in biologic tissues. While 1 Sv is equal to 1 joule/kg, Sv and Gy are not interchangeable units: *Sv* refers to the biologic effect of the radiation, while *Gy* refers to the physical energy being transferred.

TYPES OF EXPOSURE

Whole-body exposure occurs when radiation energy is deposited throughout the entire body. During a whole-body exposure, alpha and beta particles have limited penetration and do not cause significant noncutaneous injury unless emission results from an internalized source. Whole-body exposure from gamma rays, x-rays, or neutrons, which can penetrate through the body (the degree of which depends on their energy), can result in damage to multiple tissues and organs. The damage is proportional to the radiation exposure of the specific organ or tissue.

External contamination is a result of fallout of radioactive particles that land on the body surface, clothing, skin, and hair. This is the dominant element to consider in the mass-casualty situation resulting from a radioactive terrorist strike. The common contaminants primarily emit alpha and beta radiation. Alpha particles do not penetrate beyond the skin and thus have minimal systemic effects. Beta emitters can cause significant cutaneous burns and scarring. Due to their ability to penetrate tissue, gamma emitters can cause not only local damage but also whole-body radiation exposures and injury. Medical treatment primarily entails decontamination of the body, including wounds and burns, to prevent internalization of radioactive contaminants. Removal of contaminated clothing reduces levels of contamination significantly and is a first step in the decontamination process. Generally, patients do not constitute a significant radiation hazard to health care providers, and lifesaving treatment should not be delayed for fear of secondary contamination of the medical team. Although risk is relatively low, any damage to health care personnel will depend directly on the duration of exposure and will be inversely proportional to the square of the distance from any radioactive source. Gowns that can be easily removed offer protection.

Internal contamination occurs when radioactive material is inhaled or ingested or enters the body through open wounds or burns or via skin absorption. In principle, any externally contaminated casualty should be evaluated for internal contamination. Because of their chemical properties, some isotopes may exert toxic effects on specific target organs in addition to causing radiologic injury. The respiratory system is the main portal of entry for internal contamination, and the lung is the organ at greatest risk. Aerosol particles <5 μm in diameter can reach the alveoli, whereas larger particles will remain in the proximal airways. The tiny particles can be absorbed by the lymphatic system or the bloodstream. Bronchial lavage is often a helpful treatment in this situation. Radioactive material entering the gastrointestinal tract is absorbed according to its chemical structure and solubility.