Radiation Exposure

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A 16-year-old boy broke open an "EXIT" sign that he had been playing with and the gaseous contents of the lettering tubes were presumably released into the environment. A small amount of liquid spilled from the tube. Shortly thereafter, he noticed a "Caution: Radioactive" sticker on the back of the sign. The appropriate agencies (e.g., State Radiation Office, Environmental Protection Agency, Nuclear Regulatory Commission) were notified. The boy was asymptomatic but was taken for medical evaluation as a precaution. The boy's urine was found to contain approximately 30 μCuries of radioactivity; the isotope was identified as tritium.

WHAT ARE THE CONCERNS ABOUT RADIATION EXPOSURE?

Radiation may be produced in two ways. First, it may be generated through electron bombardment of an appropriate compound, which subsequently releases X-rays. This is the basis for the roentgenogram. Molecular damage may occur as the electromagnetic waves pass through the tissue, but external irradiation with X-rays does not leave the patient permanently "radioactive". Alternatively, radiation may be emitted by radionuclides such as uranium (U^{238}) or iodine (I^{131}) through the process of radioactive decay. Radionuclides may cause injury through external irradiation of the patient, by contamination (e.g., dermal), or through incorporation. Incorporation occurs when a radionuclide is inhaled, ingested, injected, or otherwise deposited inside of a human being, thus gaining direct access to the body tissues. Since many radionuclides, including tritium, emit particles that cannot penetrate intact skin, incorporation is the most consequential form of radionuclide exposure.

Three principle forms of radioactivity—alpha (α), beta (β), and gamma (γ) —are clinically important and frequently discussed, although other minor types of radioactivite particles, such as neutrons, positrons and neutrinos, also exist. Alpha particles contain two protons and two neutrons (i.e., a helium nucleus), and carry a charge of +2. Due to their size and inability to penetrate the epidermis, α particles are hazardous only if incorporated. The most recent example of the consequences of α-particle incorporation was in the presumed murder of Victor Litvinenko, a former Russian spy, by Polonium (Po^{210}). Beta particles are negatively charged electrons that are released when a neutron is transformed into a proton and an electron. These small particles may penetrate the skin up to a depth of one centimeter or so depending on their energy; like α particles, they are generally hazardous only if incorporated. This is particularly true of tritium which emits low energy β-particles. High intensity or prolonged external exposure may produce β-particle skin damage (i.e., “beta burns”), quite similar to sunburn.

Finally, γ rays are photons of ionizing electromagnetic radiation, higher in energy than X-rays; several centimeters of lead may be required to ensure protection. Unlike α and β particles, γ rays are hazardous following external exposure. Patients who are topically

contaminated, and perhaps also those who have incorporated γ-emitting radionuclides, are subject to continuous radiation exposure and *may* pose a threat to others.

WHAT ARE THE SOURCES OF RADIATION: EXPECTED AND UNEXPECTED

Tritium is commonly used in emergency lighting. Gaseous tritium releases its β-particle within a sealed tube that electrically excites a local phosphor compound. As the phosphor returns to the resting state, phosphorescence occurs through the emission of photons, or light. Because there is no need for an outside source of electricity, this is among the preferred method of illumination in critical directional signs (e.g., "Exit") that must function during a blackout or fire. These signs are available over the Internet.

Other sources of household radiation, all of which are nonhazardous if intact, include smoke detectors (Am^{241} and Ra^{226}), static eliminators (Kr^{85} and Po^{210}), electron tubes (Co^{60}, Ni^{63}, Cs^{137}), and watches (H^{3}). Historically, watch dial painters would lick the tips of their brushes in order to sharpen them. As a result, they incorporated exceedingly high levels of radium (Ra^{226}) and suffered from extraordinarily high rates of jaw and bone cancer. Ironically, radiation risk to watch wearers was miniscule due to the inability of the emitted α-particle to penetrate the watch casing. Radon (Rn^{222}), a gaseous natural decay product of uranium (U^{238}) and radium (Ra^{226}), may be found in high concentration in some homes. Radon is an unnoticeable α-emitting gas; unavoidable, high-level inhalational exposure may lead to lung cancer, which is why home testing for radon is recommended or mandatory in high-risk locations.

WHAT ARE THE CLINICAL SIGNS OF RADIATION POISONING

Nausea and vomiting are the early hallmarks of the acute radiation syndrome, which is most commonly seen following total-body external γ-irradiation. However, patients who incorporate α- or β-emitting radionuclides, such as polonium or tritium, may suffer from a similar syndrome. The more rapid the onset of these symptoms, the higher the exposure and the poorer the prognosis. If the patient survives, clinical improvement—termed the *latent phase*—may be noted in several days. However, subclinical organ damage may persist. That becomes clinically manifest about two to three weeks later, with recrudescence of gastrointestinal distress, bleeding, sepsis, and alopecia. Due to their predictable radiosensitivity, a peripheral lymphocyte count can serve as a marker for exposure and prognosis.

PATIENT OUTCOME

Several federal agencies as well as the staff of a regional nuclear laboratory assisted in the clean-up of the contaminated area. Costs of cleanup following a radioactive exit sign leak has been over $200,000. Since tritium is a gas, simple ventilation of the exposed room eliminates virtually all measurable radioactivity. The liquid that leaked from the tube was likely tritiated water. The patient was decontaminated, as were his clothes. Although the half-life of decay of tritium is about 12 years, the biological half-life of tritiated water in humans in markedly shorter—about 12 days—because it follows the body's "water cycle" is excreted in urine. For that reason, some experts have advocated forced diuresis to enhance the elimination, but this method is more likely to lead to fluid and electrolyte disturbances than to significantly increased excretion. The patient suffered

no adverse effects, and his follow-up laboratory tests remained normal. Long-term outcome and genotoxicity remain to be evaluated.

Suggested Reading

Pershagen G, et al.: Residential radon exposure and lung cancer in Sweden. *N Engl J Med* 330:159, 1994.
Finch SC. Acute radiation syndrome. *JAMA* 258:664, 1987
Saenger EL. Radiation accidents. *Ann Emerg Med* 15:1061, 1986.
NRC Information Notice 99-26: Safety And Economic Consequences Of Misleading Marketing Information
NRC Regulatory Issue Summary 2006-25: Requirements for the distribution and possession of tritium exit signs and the requirements in 10 CFR 31.5 and 32.51a