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Fluoroscopy:
Radiation Protection and Safety

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Fluoroscopy: Radiation Protection and Safety

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Advanced medical imaging modalities, particularly fluoroscopy, interventional radiology and computed tomography (CT), are associated with long exposure times and high radiation doses, making radiation protection a vital concern. In the United States, increased utilization of radiologic examinations, especially CT, has added to the effective dose to patients.

This article presents an overview of radiation protection in fluoroscopy, including radiation measurements, the biological effects of radiation, the fundamental principles of radiation protection, the ethical and legal responsibilities of medical imaging professionals, examination room design, fluoroscopy equipment safety features, and the protection of patients, personnel and special populations.

After completing this article, readers should be able to:

- Identify and justify the need to minimize unnecessary radiation exposure of humans.
- Identify sources of ionizing radiation.
- Define radiation and radioactivity units of measurement associated with radiation exposure and dose.
- Discuss the potential biological effects of ionizing radiation, including somatic, genetic, stochastic and nonstochastic effects.
- List the fundamental principles of radiation protection.
- Explain the objectives of a radiation protection program and discuss the components of an effective protection program, including documentation, occupational and nonoccupational dose limits and the ALARA principle.
- Recognize the legal and ethical responsibilities of radiation workers with respect to radiation protection.
- Discuss shielding and examination room design, including the difference between primary and secondary radiation barriers and factors affecting shielding.
- Describe various features of fluoroscopy equipment that limit radiation exposure to patients and personnel.
- Describe methods to reduce patient and personnel radiation exposure, including the use of beam-limiting devices, filtration, shielding, exposure factors, positioning, immobilization and intermittent fluoroscopy.
- Explain the special considerations required for radiation protection of children, pregnant patients and pregnant radiation workers.

Starting with the discovery of x-rays in 1895 by Wilhelm Conrad Roentgen, technological advances have given birth to a variety of medical imaging modalities, including fluoroscopy, interventional radiology and computed tomography (CT). Improvements in technology and the development of minimally invasive procedures have led to extensive use of radiologic examinations, particularly fluoroscopy-guided procedures to accurately place needles and catheters. The advantage of these procedures is that they are cost effective and often reduce the need for surgery.

Many of these imaging modalities, however, are associated with long exposure times and high radiation doses; therefore, radiation protection is important to safeguard patients, radiology personnel and the public. It is essential that all workers involved in radiologic procedures understand the risks of ionizing radiation and the need to minimize unnecessary radiation exposure.

Sources of Radiation

Exposure to ionizing radiation comes from either natural or artificial sources. Natural sources of radiation include exposure from the earth's crust, outer space, building materials and naturally occurring radioactive materials in the body.[1] Artificial radiation sources include dental and medical exposure (including diagnostic radiology, nuclear medicine and radiation therapy), fallout from nuclear weapons, the nuclear power industry and occupational radiation exposure.[1] Radon and its decay products represent the largest contributors of natural (background) radiation exposure, and medical procedures deliver the largest amount of artificial radiation to the public.[2]

Radon gas forms from the radioactive breakdown of naturally occurring radium found in soil. Individuals are exposed to natural radiation when radon gas enters buildings through small openings in the foundation. Thus, the amount of background radiation a person receives varies depending on his or her location. Different areas of the United States have different radon levels; for example, the radon levels in Colorado differ from radon levels in Florida. It is interesting that, "In two 1999 reports, the National Academy of Sciences (NAS) concluded after an exhaustive review that radon in indoor air is the second leading cause of lung cancer in the U.S. after cigarette smoking."[3]

Medical radiation comes from three sources: the treatment of benign diseases, diagnostic examinations and the treatment of malignant diseases. Data collected from the Biological Effects of Ionizing Radiation (BEIR) VII, Phase 2 study indicate that approximately 400 million diagnostic medical examinations and 150 million dental x-ray examinations are performed annually in the United States. On average, each person receives at least 2 examinations per year.[4]

Radiation Units and Measurement

Antoine Henri Becquerel discovered radioactivity in 1896; he was awarded the Nobel Prize in Physics in 1903 for his discovery, together with Marie and Pierre Curie.[5] Radioactive materials contain unstable atoms that continuously decay; the more unstable atoms are within a given substance, the greater the disintegration rate, or rate of decay. Radioactivity is expressed using the becquerel (Bq), which is the International System of Units (SI) measurement, or the curie (Ci), which is the non-SI unit. One Bq is equal to 1 disintegration per second, and 1 Ci is equal to 3.7×10^{10} Bq. The curie is equal to 2.2 trillion (2,200,000,000,000) disintegrations per minute (dpm) or 2.2×10^{12} dpm.[6,7]

Exposure

When atoms of molecules absorb x-ray energy, electrons break away from their atomic orbits, creating charged particles, or ions, thus the term "ionizing radiation."[8] Radiation exposure units include the coulomb/kilogram (C/kg) and the roentgen (R). The coulomb is a unit of electrostatic charge, and the roentgen is a unit of radiation exposure describing the ionization of atoms in air by gamma rays or x-rays up to 3 megaelectron volts (MeV). The roentgen does not measure energy absorbed or dose, but rather how many ion pairs are formed in a given volume of air when exposed to radiation.[2,9]

Absorbed Dose

Absorbed dose is defined as the energy imparted to matter by ionizing radiation per unit mass of irradiated material.[1] The measurement of absorbed dose is expressed in gray (Gy), which is the SI unit, or the older, non-SI term, radiation absorbed dose (rad). One Gy equals 100 rad and 1 rad equals 0.01 Gy. The gray describes the radiation dose absorbed by tissues following exposure to ionizing radiation. A 1-Gy dose is equal to 1 joule (J) of radiation energy absorbed per kilogram of organ or tissue weight. This unit is used to measure the dose accumulated from multiple exposures to any type of ionizing radiation. However, equal doses of different types of radiation are not equally harmful to the body. The gray or rad is not a measure of the relative biological effect on the body.[10]

Dose Equivalent

Dose equivalent is a measurement used to indicate the biological damage to living tissue from an absorbed radiation dose. It is the product of the absorbed dose and a quality factor that takes into account the effects of different types of radiation.[1] Dose equivalent is expressed in sievert (Sv), which is the SI unit, or roentgen equivalent man (rem), the conventional unit. One Sv equals 100 rem and 1 rem equals 0.01 Sv.[10]

The rem measures radiation energy absorbed by a person. For example, a chest radiograph delivers a