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Radiation Biology and Protection

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To protect themselves, their patients and their coworkers, radiologic technologists should regularly refresh and reinforce their understanding of key radiation biology and protection principles. This article reviews the concepts of radiation physics, human biology and radiation protection strategies, with emphasis on how historical events and developing research affect radiation protection understanding and practice.

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This Directed Reading Classic is about radiation protection and may qualify for state-specific radiation protection credits.

After completing this article, readers should be able to:

- *Describe the basics of cell biology, including basic cellular structures and functions.*
- *Explain how ionizing radiation may damage cellular structures and functions.*
- *Discuss the basic stages of acute radiation syndrome.*
- *Describe how the data from Hiroshima victims have influenced current understanding of the effects of ionizing radiation on human biological systems.*
- *Discuss the basic components of radiation physics, including the structure of the atom, the structure of a wave form and the types of bonds that occur.*
- *Explain how radiation units are quantified and the complexity associated with calculating specific organ and tissue absorption values.*
- *Describe occupational hazards associated with exposure to medical ionizing radiation.*
- *Recognize the professional and ethical duty to protect the patient from ionizing radiation.*
- *Explain some simple protective measures that radiologic technologists can use to protect themselves and their patients.*

Radiologic technologists are highly trained allied health practitioners who play an important role in today's health care delivery system. One of radiologic technologists' key responsibilities is providing optimal diagnostic images while using the lowest radiation dose possible. As physicians continue to make greater use of higher-dose imaging modalities such as computed tomography (CT) and interventional procedures, there is increasing concern that the public may be exposed to a greater radiation dose.

It is essential that radiologic technologists understand the basic concepts of radiation physics, human biology and radiation protection strategies to minimize the dose to themselves, their coworkers and the patients they serve. They also must be able to accurately describe radiation protection principles to patients so the public can respect the risks but not fear beneficial medical procedures.

To appreciate the nature of ionizing radiation, radiologic technologists should periodically review the basic principles of radiation physics such as the structure of the atom and the process of ionization. Radiologic technologists have both a professional and ethical duty to protect patients, coworkers and themselves from excessive ionizing radiation during medical diagnostic and interventional procedures. A variety of protective processes, procedures and equipment have been implemented to provide optimal diagnostic images with the lowest possible radiation dose to patient and technologist.

Radiation Physics

Radiologic physics is a branch of science concerned with the nature, production, quantification and effects of ionizing radiation in living things. It is critical to understand the key concepts related to ionizing radiation and its effect on the human body. A sound understanding of the background physics provides a framework for applying radiation protection strategies to protect the patient and the health care worker.

Radiation refers to any energy that is emitted and transferred through matter.[1,2] Sound is a form of radiant energy that can be detected easily by the human ear. Sound energy typically does not cause biologic damage except for extreme cases of exposure to intense sound waves. Some forms of radiant energy can ionize matter. Ionization means that the wave has the ability to remove electrons from atoms (see Figure 1).

There are natural and artificial sources of ionizing radiation. Some examples of natural sources include radium, cobalt and uranium. These elements share the characteristic of spontaneously emitting excess energy in the form of ionizing radiation to reach a stable state. This spontaneous emission of radiant energy is known as the process of decay. The rate of decay is the source's half-life.[1] Medical science has harnessed various forms of this radiant energy for the treatment of some cancers. Radiologic technologists focus primarily on the artificial, high-energy forms of electromagnetic radiation.

Electromagnetic radiation includes (in order from lowest energy to highest) radio waves, microwaves, infrared rays, visible light, ultraviolet rays, x-rays and gamma rays.[1,2] The energy of the wave form is determined by the distance between the peaks of the waves, which is known as the wavelength (see Figure 2). The higher the energy, the shorter the wavelength will be. Because x-rays and gamma rays have the highest energy, they have the shortest wavelengths. These 2 forms of electromagnetic energy also have the ability to ionize matter.

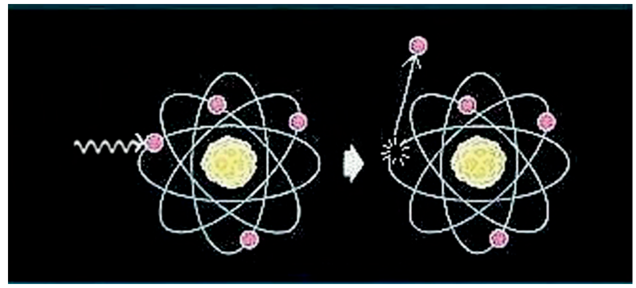

Figure 1. *Ionizing radiation includes high-speed particles and high-energy electromagnetic waves. The waves' energy is high enough to remove orbital electrons from atoms, as illustrated by the arrow, thus giving rise to positively charged ions and negatively charged electrons. Image courtesy of the Hong Kong Observatory, the Government of the Hong Kong Special Administrative Region.*

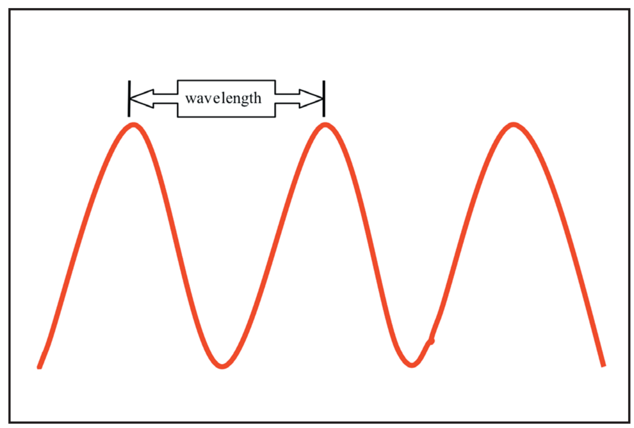

Figure 2. *The wavelength is the distance between the peaks of each waveform. The shorter the distance, the more energetic the wave. Image courtesy of Dr James Johnston, Midwestern State University, Wichita Falls, TX.*

Understanding the Atom

X-rays are produced at the atomic level. X-rays interact with matter at this level, resulting in dose and possible biologic damage to human tissue. The atom is the basic building block of matter and is made up of 3 principal parts — protons, neutrons and electrons. Protons and neutrons make up the nucleus of the atom. Electrons are the smallest of the 3 particles and orbit the nucleus in established energy levels called shells (see Figure 3). Protons have a mass of 1.673×10^{-27} kg and 1 unit of positive charge. Neutrons are slightly larger with a mass of 1.675×10^{-27} kg but no charge. Electrons have a mass of 9.109×10^{-31} kg and 1 unit of negative charge.[1-3]

An atom in a stable state will have a balance of positive and negative charges. The orbiting electrons are bound to the nucleus by a force of attraction; the closer the electron's orbit is to the nucleus, the tighter it is bound. The shells in which the electrons orbit are well defined and only a certain number of electrons can occupy each shell. A formula ($2n^2$ with "n" being the shell number) can be used to calculate the number of electrons that can occupy a shell. The "n" number in the formula begins with 1 and the shell closest to the nucleus.[3] In a stable state the shells are filled from the nucleus outward.