Chapter 2
Basic X-Ray Physics

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X-Ray Production

Interventional radiology procedures allow an interventional radiologist with highly specialized training to utilize the imaging function of a fluoroscopy system to carry out diagnostic and therapeutic procedures for a wide variety of diseases and conditions. X-ray production with a fluoroscopy unit happens much in the same way as a conventional radiography unit. Within an X-ray tube, by colliding electrons produced at high velocity from a cathode (negatively charged metal) with the atoms of the anode (a positively charged metal such as tungsten-rhenium alloy and molybdenum), energy is released in the form of X-ray photons. A key property of X-rays that differentiates them from other types of radiation is the fact that since X-rays are not particles and do not have an electrical charge, they have greater penetration power, making them effective for imaging the body [1, 2]. The voltage supplied to the cathode and the numbers of electrons emitted toward the anode over a time period are the kilovolt peak (kVp) and milliampere-seconds (mAs), respectively.

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X-Ray Interactions with Biological Tissues

The intensity of an X-ray beam decreases as it interacts with matter, due to absorption or scattering. As the X-ray photons pass through tissue, they encounter atomic electrons. Upon interaction with an electron, a photon's energy can be absorbed by the electron (photoelectric absorption), or the photon can be scattered in a different direction (Compton scattering) [1, 2].

Photoelectric absorption is key to generating the image. Different materials have different propensities for beam absorption, producing image contrast. In general, beam absorption increases with the thickness, density, and atomic number of a material. For example, since bone is more dense and has a higher atomic number than soft tissue, bone absorbs more of the X-ray beam and appears brighter than soft tissue on the radiographic image. Air absorbs very little of the X-ray beam, so it appears darker in the image.

Compton scattering, on the other hand, dampens image quality, but is an unavoidable by-product of X-ray imaging.

However, both photoelectric absorption and Compton scattering generate damaging ions in tissue. If an electron absorbs enough energy from a photon, it can be ejected from an atom. Ejected electrons can damage DNA directly or react with other molecules, such as water, to generate free radicals. Free radicals are highly reactive and cause damage to DNA and other cell constituents [3, 4]. The biological effects of ionizing radiation can be classified as either somatic or genetic.

Somatic Effects

Somatic effects manifest in the irradiated individual. Stochastic effects (e.g., cancers) occur in keeping with the linear no-threshold (LNT) model, where there is no threshold dose for damage to occur, but higher doses increase the probability of disease. Deterministic effects (e.g., cataracts) occur depending on how much cumulative radiation dose a person has received [4]. Examples include:

- Cancer—leukemia, thyroid, breast, lung, gastrointestinal, skin
- Skin effects—erythema, desquamation, hair loss
- Gastrointestinal epithelia—sloughing off negatively impacting digestion and nutrient absorption
- Bone marrow—anemia, immunosuppression
- Lung tissue—radiation pneumonitis, pulmonary fibrosis, mesothelioma

Genetic Effects

Genetic and teratogenic effects do not yield observable effects in the irradiated individual, but rather in his or her offspring. Genetic effects are those passed on from parent to child as a result of point mutations, single-stranded breaks, or double-stranded breaks in germline cells impacting the future development of the progeny [4]. Teratogenic effects occur when a developing fetus is exposed to radiation and manifest as:

- Childhood cancer
- Microcephaly
- Poorly formed eyes
- Slow growth
- Mental retardation

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