CHARACTERISTIC RADIATION

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Fundamental of Radio Physics
Fall semester
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Outline

Characteristic radiation

- Importance in Imaging and Dose
- Influence of Electron Energy
- Influence of Target Material
- Influence of Filtration

Objectives

The student should be able to do the followings;

- Define characteristic radiation
- Explain the importance of characteristic radiation in imaging and dose
- Analyze the influence of electron energy
- Explain the influence of target material on the dose
- Evaluate the influence of filtration on output dose

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Characteristic radiation

X rays released as characteristic radiation have energies independent of that of the bombarding electrons so long as the energy of the bombarding electrons exceeds the threshold energy for characteristic x ray emission. The energy of the bombarding electrons varies with tube voltage, which fluctuates rapidly in some x-ray tubes.

X rays are produced at a range of depths in the target of the x-ray tube. These x-rays travel through different thicknesses of target and may lose energy through one or more interactions.

Changes in other variables such as filtration, target material, peak tube voltage, current, and exposure time all may affect the range and intensity of x-ray energies in the useful beam.

Importance in imaging and dose

Radiation exposure is measured in SI units of C/kg, measured in mGy. Because mGy is also a unit of dose.

Absorbed Dose (Gy_t). Biologic effects usually are related to the **r**adiation **a**bsorbed **d**ose (rad). Absorbed dose is the radiation energy absorbed per unit mass and has units of J/kg or Gy_t. The units Gy_a and Gy_t refer to radiation dose in air and tissue, respectively.

X-ray tubes are designed so that projectile electrons from the cathode interact with the target only at the focal spot. However, some of the electrons bounce off the focal spot and then land on other areas of the target, causing x-rays to be produced from outside of the focal spot.

For characteristic x-ray, the additional x-ray beam area increases skin dose modestly but unnecessarily. Off-focus radiation can significantly reduce image contrast.

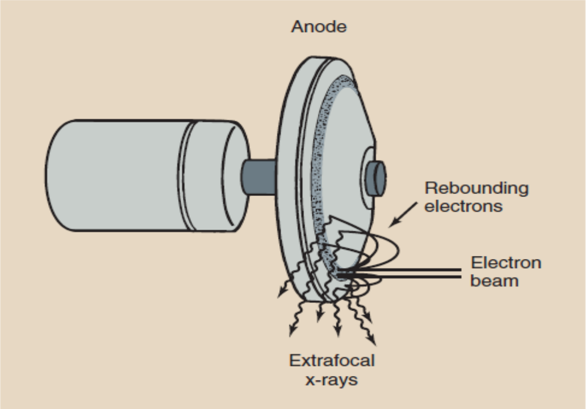

FIGURE 6-23 Extrafocal x-rays result from interaction of electrons with the anode off of the focal spot.

influence of x ray on dose and imaging

Low-energy x-rays contribute nothing useful to the image. They only increase the patient radiation dose unnecessarily because they are absorbed in superficial tissues and do not penetrate to reach the image receptor.

TABLE 8-1 Factors That Affect X-ray Quantity and Image Receptor Exposure

The Effect of Increasing	X-ray Quantity Is	Image Receptor Exposure Is
mAs	Increased proportionately	Increased
kVp	Increased by $\left(\frac{kVp_2}{kVp_1}\right)^2$	Increased by $\left(\frac{kVp_2}{kVp_1}\right)^5$
Distance	Reduced by $\left(\frac{d_1}{d_2}\right)^2$	Reduced by $\left(\frac{d_1}{d_2}\right)^2$
Filtration	Reduced	Reduced

kVp, Kilovolt peak; *mAs*, milliampere seconds.

influence of electron energy

For any projectile electron emitted by the x-ray tube filament, a greater number of x-rays are produced when the electron energy is high than when it is low. Low-voltage ripple increases radiation quality because fewer low-energy projectile electrons pass from cathode to anode to produce low-energy x-rays. Consequently, the average x-ray energy is greater than that resulting from high-voltage ripple modes.

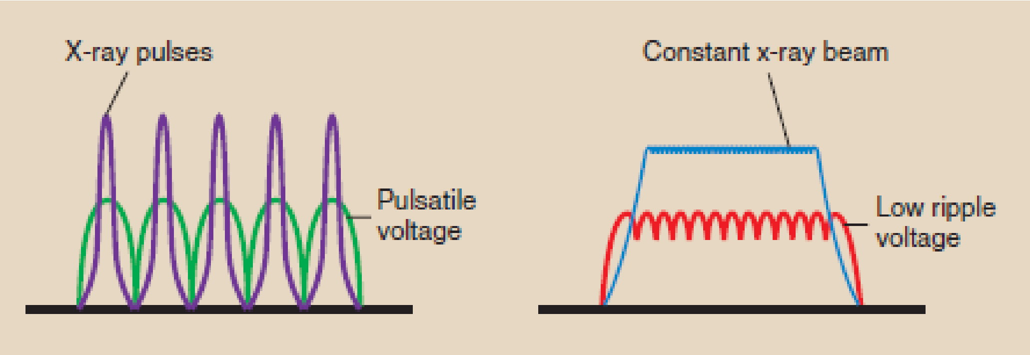

FIGURE 5-30 Both the number of x-rays and the x-ray energy increase as the voltage waveform increases.

Efficiency of converting electron energy into x rays as a function of tube voltage.[4]

kV	Heat (%)	X Rays (%)
60	99.5	0.5
200	99	1.0
4000	60	40

influence of target material

The choice of target material in an x-ray tube affects the efficiency of x-ray production and the energy at which characteristic x rays appear. If technique factors (tube voltage, milliamperage, and time) are fixed, a target material with a higher atomic number (Z) will produce more x rays per unit time by the process of bremsstrahlung. The efficiency of x-ray production is the ratio of energy emerging as x radiation from the x-ray target divided by the energy deposited by electrons impinging on the target.

X-ray production is a very inefficient process, even in targets with high atomic number. For x-ray tubes operated at conventional voltages, less than 1% of the energy deposited in the target appears as x radiation. Almost all of the energy delivered by impinging electrons is degraded to heat within the target.

The characteristic radiation produced by a target is governed by the binding energies of the K, L, and M shells of the target atoms. Theoretically, any shell could contribute to characteristic radiation.

In practice, however, transitions of electrons among shells beyond the M shell produce only low-energy x rays, ultraviolet light, and visible light. Low-energy x rays are removed by inherent filtration and do not become part of the useful beam.

influence of filtration

An x-ray beam traverses several attenuating materials before it reaches the patient, including the glass envelope of the x-ray tube, the oil surrounding the tube, and the exit window in the tube housing. These attenuators are referred to collectively as the inherent filtration of the x-ray tube (Table 5-1). The aluminum equivalent for each component of inherent filtration is the thickness of aluminum that would reduce the exposure rate by an amount equal to that provided by the component. The inherent filtration is approximately 0.9 mm Al equivalent for the tube described in Table 5-1, with most of the inherent filtration contributed by the glass envelope. The *inherent filtration* of most x-rays tubes is about 1 mm Al.

TABLE 5-1 Contributions to Inherent Filtration in Typical Diagnostic X-Ray Tube

Component	*Thickness (mm)*	*Aluminum-Equivalent Thickness (mm)*
Glass envelope	1.4	0.78
Insulating oil	2.36	0.07
Bakelite window	1.02	0.05

[a] Data from Trout, E. *Radiol. Technol.* 1963; 35:161.

influence of filtration

The inherent filtration of an x-ray tube "hardens" the x-ray beam. Additional hardening may be achieved by purposefully adding filters of various composition to the beam. The total filtration in the x-ray beam is the sum of the inherent and added filtration as shown in Table 5-1. Usually, additional hardening is desirable because the filter removes low-energy x rays that, if left in the beam, would increase the radiation dose to the patient without contributing substantially to image formation.

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References

- Al-Qurashi M., and Qasim H., . (2015). *Radiation Physics and its Applications in Diagnostic Radiological techniques.* Medical technical University, Iraq
- Hendee W., and Ritenour E.,. (2002). *Medical Imaging Physics*. Willy-Liss,Inc