Fundamentals of Radio-physics

First Semester

Lecture 5: Factors Affecting X-ray Emissin Spectrum
(Quality and Quantity of X-Ray)

By

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2023-2024

X-Ray Quantity

X-ray quantity is the number of x-ray photons in the useful beam.

The intensity is a measure of quantity of radiation. The term exposure is often used in radiology

X-Ray Quality

The term quality describes the penetrating power of the radiation.
The penetrability of an x-ray beam is called the x-ray quality. X-rays with high penetrability are termed high-quality x-rays

- **High-energy x-rays** are able to penetrate tissue more deeply than low- energy x-rays.

X- rays with high penetrability are **termed high-quality x-rays**

Factors That Affect X-ray Quantity and Quality

A number of factors under the control of radiographers influence the size and shape of the x-ray emission spectrum and therefore the quality and quantity of the x-ray beam

Exposure Time

Exposure time determines the length of time over which the x-ray tube produces x-rays.

- An increase or decrease in mA, exposure time, or mAs directly affects the quantity of x-rays produced;
- Patient dose is directly proportional to exposure time.
- **Automatic Exposure Control (AEC)**: These devices terminate the exposure when a specific quantity of radiation has reached the IR

Effect of mA and mAs (Tube Current and Time)

The product of tube current in milliamperes and exposure time in seconds (mA * sec) describes the total number of electrons bombarding the target

Calculating mAs

mAs = mA x seconds

Examples:

200 mA x 0.25 s = 50 mAs

500 mA x 2/5 s = 200 mAs

Example: Calculate the total number of electrons bombarding the target of an x-ray tube operated at 200 mA for 0.1 sec

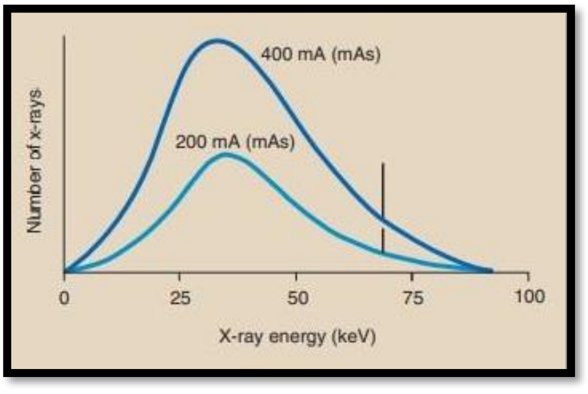
- The ampere, the unit of electrical current, equals 1 coulomb/sec.
- The product of current and time equals the total charge in coulombs.
- X-ray tube current is measured in milliamperes, where 1 mA = 10^{-3} amp.
- The charge of the electron is 1.6×10^{-19} coulombs, so

$$1\ \text{mA .s} = \frac{(10^{-3}\ \text{coulomb/sec})(\text{sec})}{1.6\times10^{-19}\ \text{coulomb/electron}}$$

= 6.25×10^{18} electronsNo. of electron = (200 mA)(0.1 sec)(6.25×10^{18} electrons/mA.sec)
= 1.25×10^{16} electrons

Remember that mAs is just a measure of the total number of electrons that travel from cathode to anode to produce x-rays.
mAs = mA × s
= mC/s × s
= mC
where C (coulomb) is a measure of electrostatic charges and 1 C = 6.25×10^{18} electrons.

A change in mA or mAs results in a proportional change in the amplitude of the x-ray emission spectrum at all energies.



X- ray quantity is directly proportional to the mAs

$$\frac{I_1}{I_2} = \frac{mAs_1}{mAs_2}$$

where I1 and I2 are the x-ray intensities at mAs1 and mAs2, respectively

Example2: The radiographic technique for a kidneys, ureters, and bladder (KUB) examination uses 74 kVp/60 mAs. The result is a patient exposure of 2.5 mGya. What will be the exposure if the mAs can be reduced to 45 mAs?

$$\frac{I_1}{2.5\text{mGya}} = \frac{45}{60}$$

$$I_1 = \frac{2.5mGya \times 45}{60} = 1.9 \text{ mGya}$$

The tube current affects only the quantity or the amount of x-ray photons produced but not the quality of the X-rays.

i.e. the intensity is α mA.

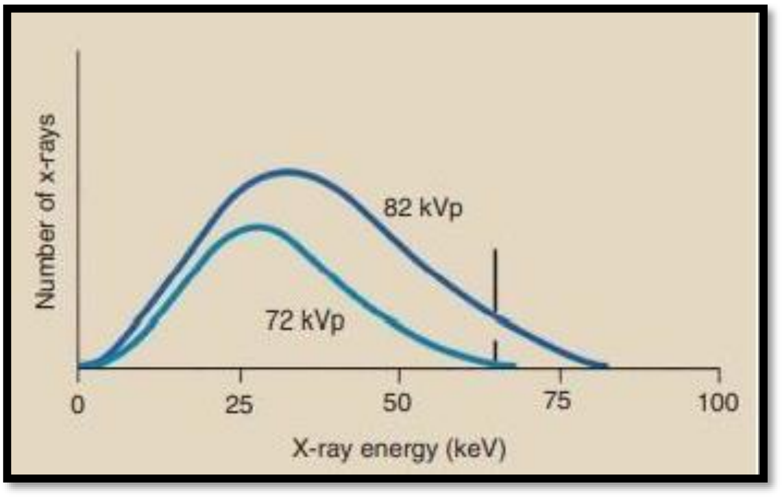
Milliamperage (mA) is a measure of the current flow rate in the x-ray tube circuit. It determines the number of electrons available to cross the tube and thus the rate at which x-rays are produced.

Effect of Kilovolt Peak (kVp) (Tube Voltage)

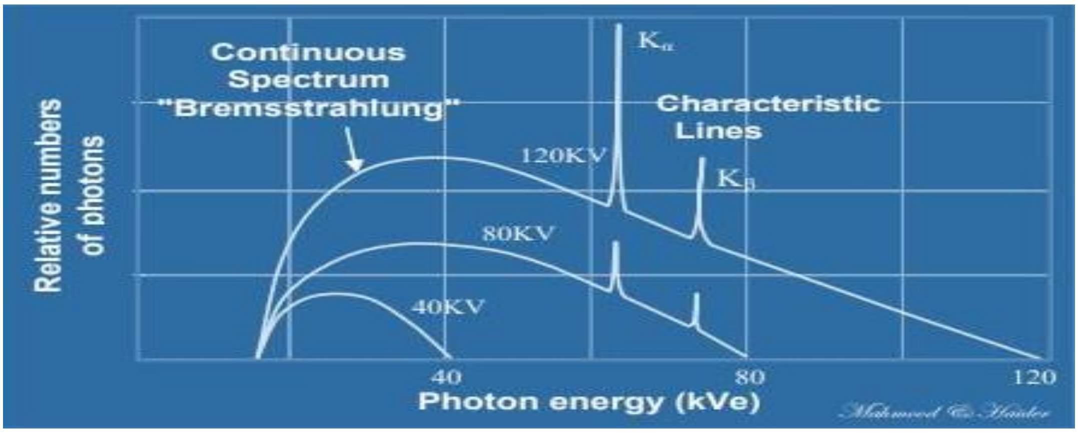
When kVp is increased:

- The maximum photon energy
- the X-ray production efficiency
- The intensity
- Quality of the X-rays

A change in kVp affects both the amplitude and the position of the x-ray emission spectrum.



A change in kVp has no effect on the position of the discrete x-ray emission spectrum



The rule states that a 15% increase in kVp is equivalent to doubling the mAs.

❖ A 15% increase in kVp does not double the x-ray intensity but is equivalent to doubling the mAs to the image receptor.

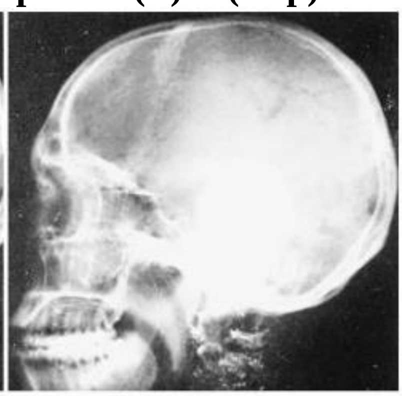
❖ To double the output intensity by increasing kVp, one would have to raise the kVp by as much as 40%.

❖ Radiographically, only a 15% increase in kVp is necessary because with increased kVp, the penetrability of the x-ray beam is increased.

❖ Therefore, less radiation is absorbed by the patient, leaving a proportionately greater number of x-rays to expose the image receptor

i.e. Radiation exposure (E) ∝ (kVp)

70 kVp / 120 mAs
665 mR



80 kVp / 60 mAs
545 mR

90 kVp / 30 mAs
230 mR

In other words, if were doub[led, the x-ray intensity would increase by a factor of four.

$$\frac{I_1}{I_2} = (\frac{kvp_1}{kvp_2})^2$$

Where $I_1$and I_2 are the X-ray intensities at KVp_1 and KVp_2,respectively

Example: A lateral chest technique calls for 110 kVp, 10 mAs and results in an x-ray intensity of 0.32 mGy_a. What will be the intensity if the kVp is increased to 125 KVp and the mAs remains fixed?

$$\frac{I_1}{I_2} = (\frac{kvp_1}{kvp_2})^2$$

$$\frac{0.32\text{mGya}}{I_2} = (\frac{110}{125})^2$$

$$I_2=(0.32\text{mGya})\ (\frac{125}{110})^2$$

$$I_2=(0.32\text{mG}ya)(1.14)^2$$

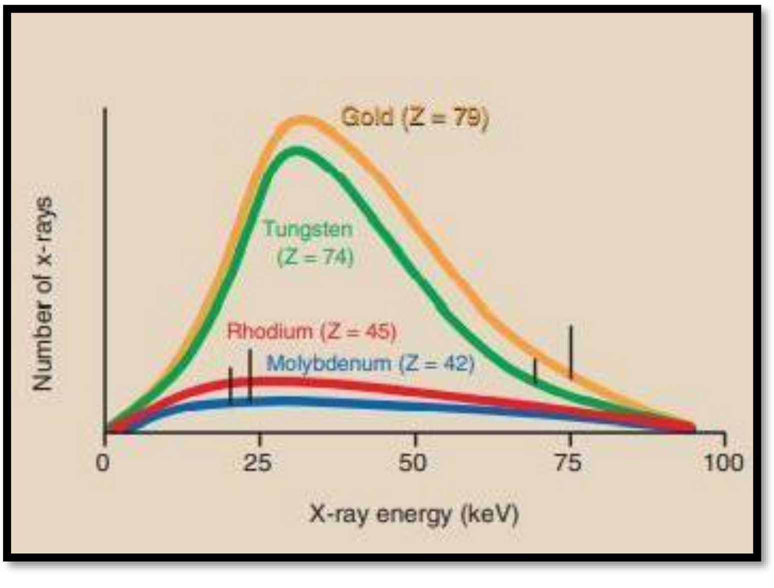
$$I_2=(0.32\text{mG}ya)(1.29)=0.41\text{mG}ya$$

Effect of Target Material

The atomic number of the target affects both the number **(quantity)** and the effective energy **(quality)** of x-rays.

As the atomic number of the target material increases:

- Increase characteristic energy
- enhances the efficiency of x-ray production
- Increase energy of bremsstrahlung x-rays.

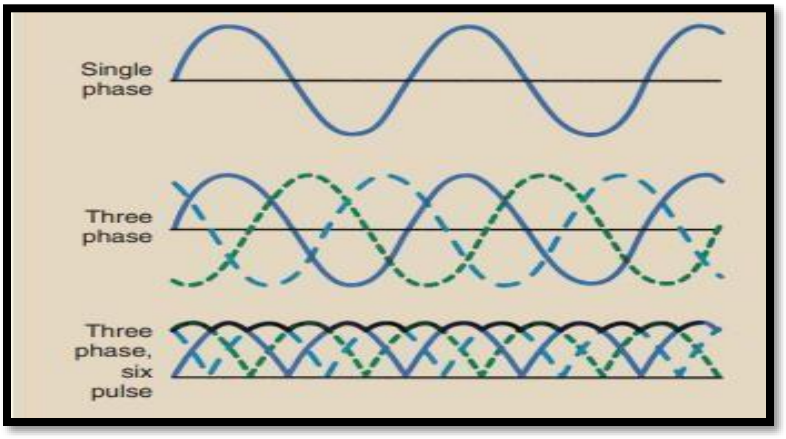


Effect of Voltage Waveform

 There are five voltage waveforms: half-wave–rectified, full-wave–rectified, three-phase/six-pulse, three-phase/ 12-pulse, and high-frequency waveforms

 The x-rays produced when the single-phase voltage waveform has a value near zero are of little diagnostic value because of their low energy; such x-rays have low penetrability.

 With three-phase power, the voltage applied across the x-ray tube is nearly constant, never dropping to zero during exposure.



• High-frequency generators produce a nearly constant potential voltage waveform, **improving image quality at lower patient radiation dose.**

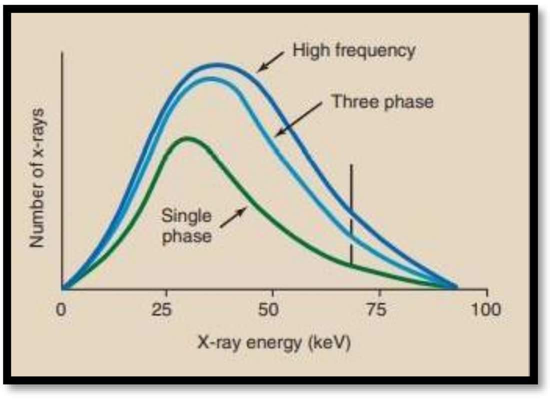
Where an x-ray emission spectrum from a full-wave–rectified unit, all operated at 92 kVp and at the same mAs:

 The x-ray emission spectrum that results from high-frequency operation is more efficient than that produced with a single-phase or a three phase generator

 Increased quantity of x-ray photons

 Increased average energy

 Minimum and maximum energy is constant



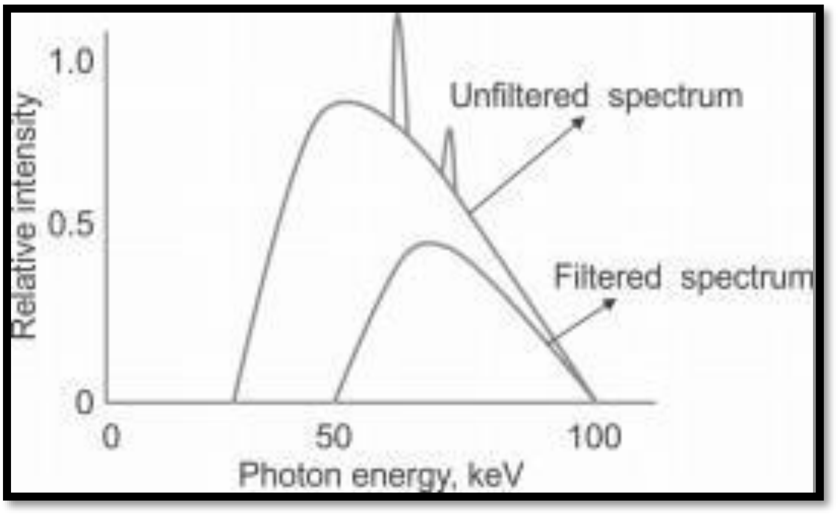
Effect of Added Filtration

 Filters are thin sheet of material (Al,Cu).

 The purpose of using filter is to reduce patient exposure at the skin level.

 Filters alter both the quality and quantity of X-rays by selectively removing the low energy photons in the spectrum.

 This reduces the photon number (quantity) and shifts the average energy to higher values by increasing the quality



An Increase in	Results in
Current (mAs)	An increase in quantity; no change in quality
Voltage (kVp)	An increase in quantity and quality
Added filtration	A decrease in quantity and an increase in quality
Target atomic number (Z)	An increase in quantity and quality
Voltage ripple	A decrease in quantity and quality