X-RAY ABSORPTION AND X-RAY QUALITY

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Fundamental of Radio Physics

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Week 7

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Outline (lectures 7+8)

X-ray absorption and x-ray quality

- The patient soft tissue and contrast agent

- Differential absorption (dependence on atomic number, and mass density)
- X-ray emission (factors influencing x-ray spectra and output: x-ray quantity and x-ray intensity)
- Factors affecting x-ray quantity

Objectives

The student should be able to do the followings; - Describe x-ray absorption inside (patient soft tissue and contrast agent)

- Explain absorption of x-ray (dependence on atomic number, and mass density)

- Differentiate factors of x-ray emission (factors influencing x-ray spectra and output: x-ray quantity and x-ray intensity)

- Mention factors affecting x-ray quantity

- Explain factors affecting x-ray quality

The patient soft tissue and contrast agent

- Contrast agents may be used to further enhance the signal from the blood vessels.
- The excellent contrast resolution might be achievable among tissues if ways could be developed to produce impedance images with satisfactory spatial resolution.
- The contrast resolution is sensitive to very small changes in tissue composition.
- X-rays normally show soft tissues poorly due to similar densities, so contrast agents like iodine or barium are sometimes used to make them more visible by absorbing X-rays differently

Differential absorption (dependence on atomic number, and mass density)

Differential absorption of x-rays is dependent on the material's atomic number (Z) and mass density (ρ), with a lesser dependence on x-ray photon energy.

- **Higher atomic numbers (Z)** increase absorption, especially photoelectric absorption (propotional with Z^3 to Z^4), A higher atomic number means a greater number of electrons in the atom, increasing the probability of an x-ray photon being absorbed through interactions like the photoelectric effect.
- **Greater mass density (ρ)** increases absorption because there are more atoms per unit volume to interact with, and both photoelectric and Compton effects are proportional to mass density.
- **Bone vs. soft tissue:** Bone appears lighter on an x-ray image compared to soft tissue because it has a higher mass density and higher atomic number, leading to more absorption of x-rays.

X-ray emission (factors influencing x-ray spectra and output: x-ray quantity and x-ray intensity)

- X-ray emission is influenced by factors including

1- tube voltage (kVp) 2- tube current (mA) 3- exposure time,

4- distance 5- filtration 6- anode material.

- **X-ray quantity** (number of photons) is primarily affected by ***mAs*** (milliampere-seconds) and distance,
- while **X-ray quality** (penetrating power) is mainly determined by ***kVp*** and filtration.
- Changes in kVp also shift the entire spectrum to higher energies, affecting both quantity and quality.
- **Filtration** decreases quantity by absorbing low-energy photons and Increases quality by removing the lowest energy photons
- **Anode Material** increases quantity in proportion to the atomic number (Z) of the anode
- **Generator Waveform** affects the overall output; a waveform with less ripple results in higher quantity and quality.

X-ray emission (factors influencing x-ray spectra and output: x-ray quantity and x-ray intensity)

- **X-ray spectrum quantity :** refers to the number of photons within the primary x-ray beam and is measured by mAs (milliampere-seconds)

- **X-ray intensity** of the beam: is defined as rate of flow of energy per unit area perpendicular to the beam, also known as energy fluence rate, with units of $W.mm^{-2}$.
- The intensity of the beam decreases by inverse square law.

Factors affecting x-ray quantity

- **Factors affecting x-ray quantity include :**

1- mAs (milliampere-seconds): This is a combination of tube current (mA) and exposure time..

2- Kilovoltage peak (kVp) : The quantity of x-rays is proportional to the square of the kVp.

3- Distance: The quantity of X-rays varies inversely with the square of the distance from the source, according to the inverse square law.

4- Filtration: Increasing filtration reduces the x-ray quantity by removing low-energy photons from the beam.

5- Target material: The atomic number (Z) of the target material affects quantity, with higher atomic numbers producing more X-rays.

6- Generator type: The type of voltage waveform produced by the generator also affects quantity; for example, a lower ripple waveform increases the quantity

Factors affecting x-ray quality

- **X-ray quality**: describes the penetrating power of x-ray beam which is quantified by HVL.
- **Image Quality:** is defined by Sensitivity, Contrast, Sharpness, and Graininess: These four core parameters determine how clearly a radiograph reveals internal features and flaws, with sensitivity referring to the smallest detectable detail.
- **Factors affecting x-ray quality** (penetrability) are:

1. kVp: x-ray penetrability is increased as kVp is increased.
2. Filtration: x-ray penetrability is increased when filters added to the beam.

Higher kVp and added filtration result in higher quality, more penetrating x-rays.

Factors affecting x-ray quality

Photon Energy Range: The general range for X-ray photon energies is from approximately 100 eV to 100 keV.

Imaging-Specific Range: The most useful range for medical imaging is between 12.4 keV and 124 keV

low-energy photons lack the penetration power for thick materials, while very high-energy photons can reduce image contrast

Factors influencing HVL: The HVL is not a fixed value but is affected by several factors, most notably the x-ray tube voltage (kVp).

The HVL range can be from 1.3 mm Al up to 13.5 mm Al, depending on the total filtration.

A higher HVL signifies a more penetrating beam because it contains a greater proportion of higher-energy photons

References

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