Theoretical Lecture

KVp adjustment & mA control

KVp Adjustment

Kilovoltage peak (kVp) the kilovoltage applied to the x-ray tube, which accelerates electrons from the cathode to the anode. Tube voltage, determines the quantity (intensity) and quality (energy) of the photons generated.

An increase in kVp extends and intensifies the x-ray emission spectrum, such that the maximal and average/effective energies are higher and the photon number/intensity is higher.

The energy of the photon emitted from the X-ray tube depends on the energy of the electrons that bombard the target. The energy of the electron is, in turn, determined by the peak kilovoltage used.

As the applied voltage increases, the effective photon energy also increases. The maximum photon energy is proportional to the peak value of the applied voltage. In addition, the X-ray production efficiency is related with applied voltage. The intensity increases with increase of applied voltage (Figure1). The amount of radiation produced increases as the square of the kilo voltage,

$$\textbf{Radiation exposure} \propto (\textbf{kVp})^2$$

Thus, increase in kVp increases the quality, quantity and efficiency of X-ray production.

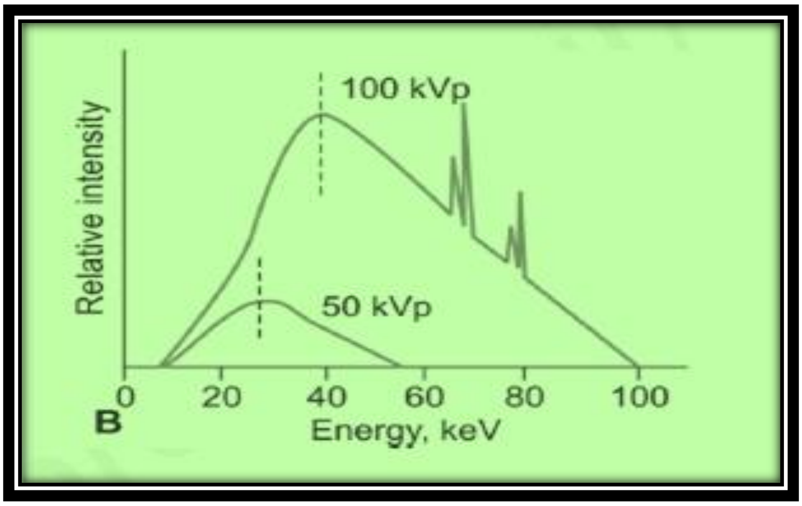

Figure1: effect of kilovoltage (Kvp) on x-ray spectra.

Image quality

The considerations that should be taken to adjust the voltage:

- The first consideration when selecting the kVp is ensuring adequate **penetration** and **exposure**, which depends on photon number, photon energy, and tissue attenuation (which depends on attenuation coefficient and thickness).
  There must be an adequate number of sufficiently energetic photons that penetrate the patient and reach the image receptor. Exposure at the image receptor increases approximately by the fifth power of the change in kVp (due to a combination of increased photon number and penetrability), such that a 15% increase in kVp doubles the intensity at the detector.
- The next consideration for adjusting kVp is image contrast (figure 2). kVp, has a great effect on image contrast. A lower kVp will make the x-ray beam less penetrating , this result in a greater difference in attenuation between the different parts of the subject, leading to higher contrast.

- A higher kVp will make X-ray beam more penetrating, this will result in less difference in attenuation between the different parts of the image, leading to lower contrast.

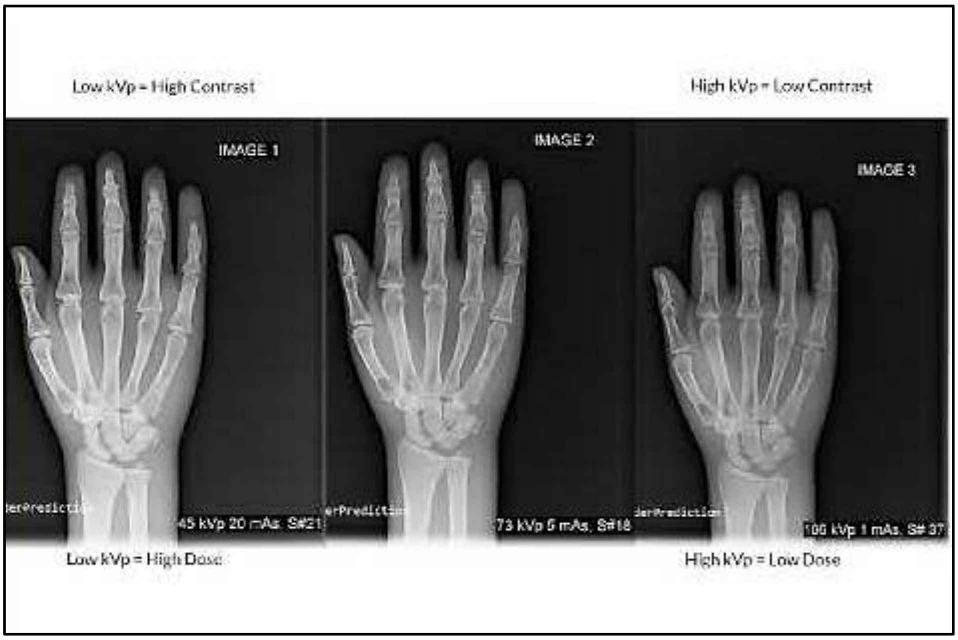

Figure 2: KVp and image contrast.

- ***To conclude;*** high KVp means higher energy photons are more likely to travel through the patient without any tissue interaction. Consequently, higher energy x-ray beams generate images with poorer contrast.

Tube Current (mA)

The number of X-rays produced depends on the number of electrons that strike the target of the X-ray tube. The number of electrons depends directly on the tube current (mA) used. Greater the mA, higher the electrons that are produced, and hence, more X-rays will be obtained.

The tube current affects only the intensity (quantity) but not the quality of the X-rays (figure 3). As the tube current increases the intensity also increases.

The intensity is $\propto$ mA.

Increase of applied voltage is compensated by the reduction of tube current, which is required to maintain same exposure.

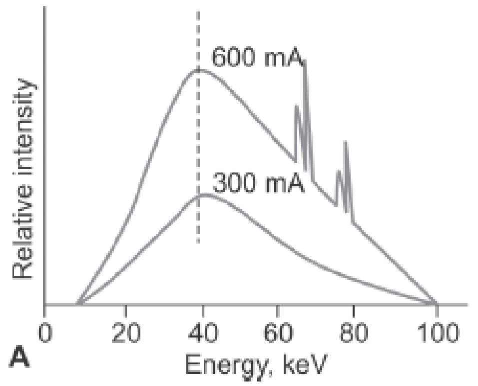

Figure3: effect of tube current (mA) on x-ray spectra.

Milliampere-seconds (mAs)

Milliampere-seconds more commonly known as **mAs** is a measure of radiation produced (milliamperage) over a set amount of time (seconds) via an x-ray tube. It directly influences the radiographic density, when all other factors are constant.

The time factor (s) is a measure of the electrons production duration in the tube; meaning prescribes how long mA will last.

For example:

mA x t = mAs

600 mA x 0.1 sec. = 60 mAs

Increasing either the current or time will increase the quantity of radiation; therefore the amount of radiation in an examination is represented as mAs.

Exposure Timer & checking a timer

Exposure Timers

The exposure timers control the length of an X-ray exposure. There are two basic types of exposure timers, namely, electronic timers, and automatic exposure control (AEC).

1- Electronic Timers

In electronic timer, the length of the X-ray exposure is determined by the time required to charge a capacitor through a resistance. When the exposure button starts exposure, it also starts charging a capacitor. The exposure time is terminated, when the capacitor is charged to a specified value, necessary to turn on associated electronic circuit. This time can be varied by varying the value of the resistance in the charging circuit. Modern generators use electronic timers, in order to obtain very accurate exposure duration. These timers can accurately control exposures from < 1 ms to > 1 s.

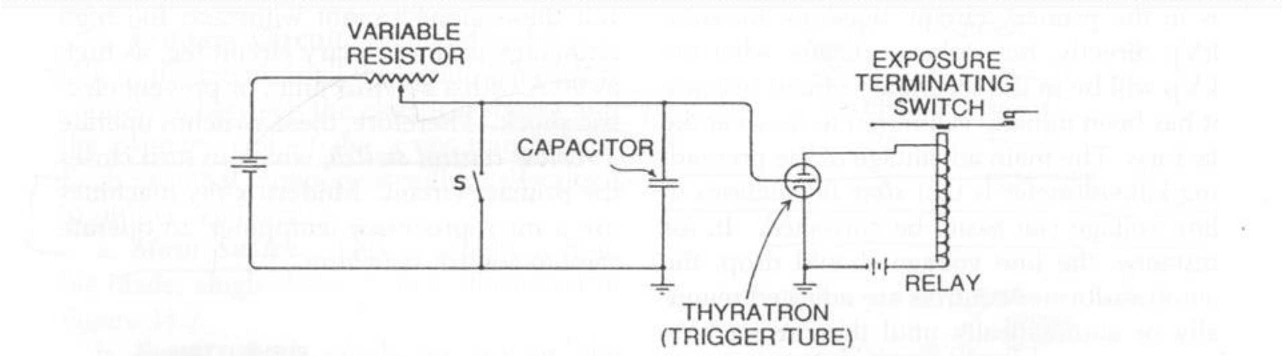

Figure 4: simplified circuitry of an electronic timer.

2- Automatic Exposure Control (AEC)

a. Phototimers

Phototimers use a fluorescent (light-producing) screen and a device that converts the light to electricity. A photomultiplier (PM) tube is an electronic device that converts visible light energy into electrical energy. A photodiode is a solid-state device that performs the same function. Phototimer AEC devices are considered exit-type devices because the detectors are positioned behind the image receptor (Figure 2) so that radiation must exit the image receptor before it is measured by the detectors.

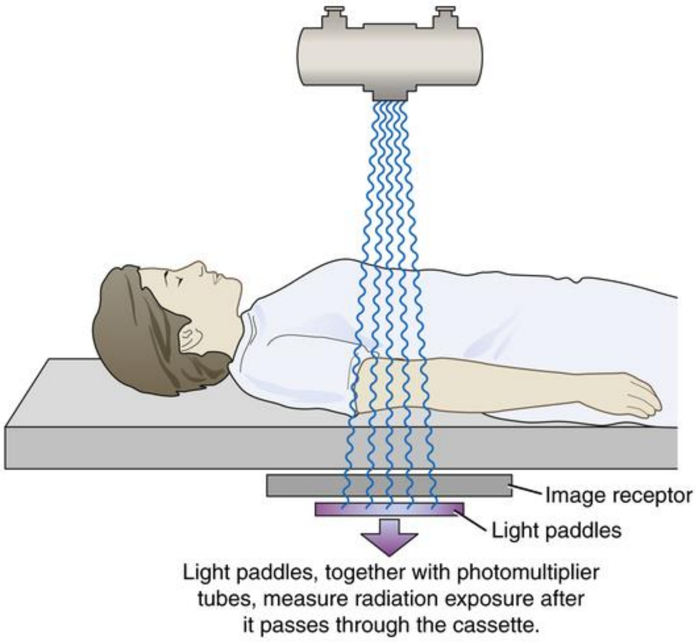

Figure 5: Phototimer Automatic Exposure Control. In the phototimer automatic exposure control system, the detectors are located directly below the image receptor. This is an exit-type device in that the x-rays must exit the image receptor before they are measured by the detectors.

Light paddles, coated with a fluorescent material, serve as the detectors, and the radiation interacts with the paddles, producing visible light. This light is transmitted to remote PM tubes or photodiodes that convert this light into electricity. The timer is tripped and the radiographic exposure is terminated when a sufficiently large charge has been received. This electrical charge is in proportion to the radiation to which the light paddles have been exposed. Photo timers have largely been replaced with ionization chamber systems.

b. Ionization Chamber Systems

An ionization or ion chamber is a hollow cell that contains air and is connected to the timer circuit via an electrical wire figure 3.

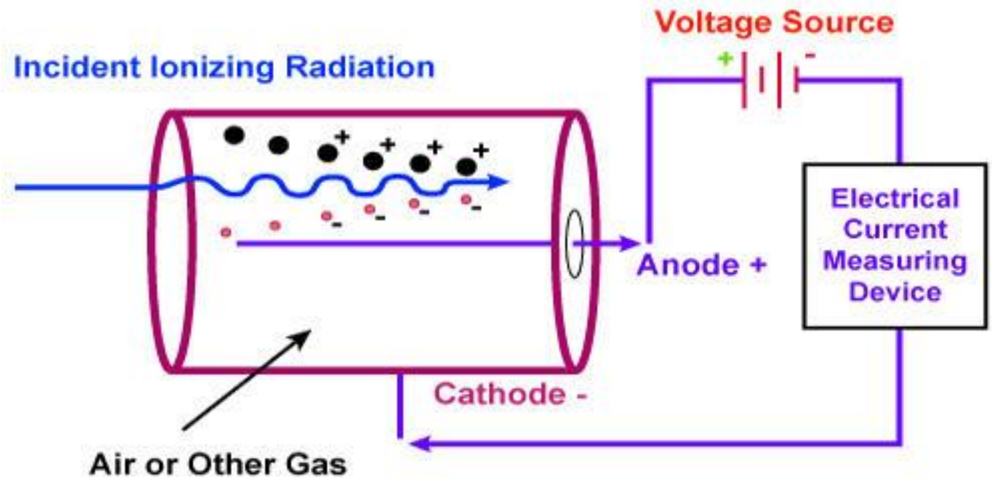

Figure 6: schematic of ionization chamber.

Ionization-chamber AEC devices are considered entrance-type devices because the detectors are positioned in front of the image receptor (Figure 4) so that radiation interacts with the detectors just before interacting with the image receptor. When the ionization chamber is exposed to radiation from a radiographic exposure, the air inside the chamber becomes ionized, creating an electrical charge. This charge travels along the wire to the timer circuit. The timer is tripped and the radiographic exposure is terminated when a sufficiently large charge has been received. This electrical charge is in proportion to the radiation to which the ionization chamber has been exposed. Compared with phototimers, ion chambers are less sophisticated and less accurate, but they are less prone to failure. Most of today's AEC systems use ionization chambers.

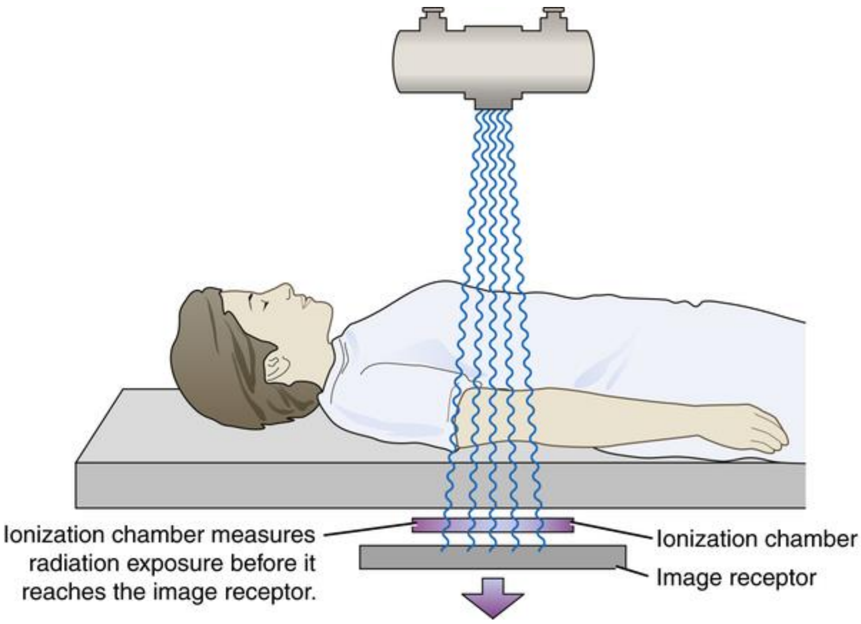

Figure 7: Ionization Chamber Automatic Exposure Control. The ionization chamber automatic exposure control system has the detectors located directly in front of the image receptor. This is an entrance-type device because the x-ray exposure is measured just before entering the image receptor.

Checking a timer:

If the exposure time set on the diagnostic x-ray unit is not optimal, the radiograph can be under exposed or over exposed. This may lead to repeat examinations. Hence, there is a need to test the timer of the x-ray unit **periodically.**

Spinning Top Test Tool

- Spinning top test tool (figure 5) is used to check the exposure time.
- It consist of a rotating circular brass plate with small rectangular portion cut (hole) at its periphery.
- The tool is placed on the cassette, loaded with film. For a set time, the unit is energized, while the top is rotating.
- The pulses passing through the hole of the circular plate, produces equally spaced rectangular density patterns, on the film.

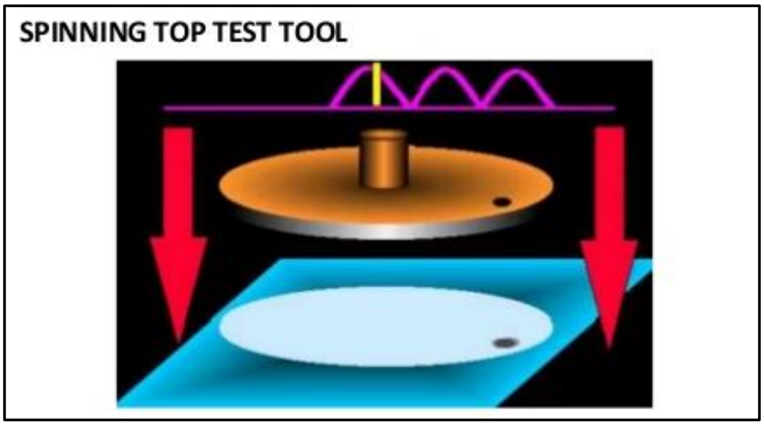

Figure 8: spinning top test.

Questions:

1. Define KVp?
2. What are the consideration that should be taken to adjust the KVp?
3. How the KVp effect the contrast image?
4. What does the mAs mean?
5. What are the KVp and mA effect on?
6. How the electronic timers work?
7. What are the types of automatic exposure control (AEC)? Explain on of them?
8. What is the entrance type device of AEC?
9. How can you checking the exposure time?