Chapter one

Introduction

1.1. Introduction:

The principle goal of quality assurance of x-ray machine is to obtain accurate and timely diagnosis. The secondary goals are minimization of radiation exposure and obtain high image quality. This can be assess by performance the x-ray machine by optimum operating parameters such as reproducibility of tube voltage, dose output, time , x-ray tube efficiency , Accuracy of kVp , mA , time , focal spot size . and half value layer.

Many authors published work concerning quality assurance of x-ray machine, describes quality assurance protocol for diagnostic x-ray equipment at the radiologic technologist level. Some important parameters in diagnostic x-ray such as film processor monitor, exposure time, mAs reciprocity, peak tube potential, and x-ray output and beam quality, and focal spot size were described. (Bosnjak et.al 2008) has been systematically performed quality control surveys of diagnostics imaging equipment.

(Johns, 1961) had been expressed the quality of x-ray in terms of the half value Layer. Contribution of radiology to better diagnoses and treatments is evident. In parallel, efforts were oriented towards the improvement and control of equipment. The importance of quality assurance (QA) of diagnostic X-ray equipment is well recognized.

Application of QA programme is very important when optimization of image quality and reduction of patient exposure is desired.

For Diagnostic purposes, the optimizations of exposure involve the relationship of three core aspects:

i) Choice of radiographic technique

ii) Radiation dose to the subject.

iii) Diagnostic quantity of the radiographic image.

These three aspects are critical for the diagnostic quantity of the radiographic image.

The four main exposure parameters are:

tube potential (kV), tube intensity (mA), exposure time (s) and focus to detector distance (cm). Exposure time and tube intensity could be a unique exposure factor (mAs).The kVp is the factor which controls the energy of the electrons as they move across the tube, or the speed of the electrons. The higher the kVp the greater the impact of the electrons with the target or anode. The greater the kVp the greater the penetration. The "p" stands for peak, therefore kVp means kilo voltage peak. Peak denotes highest voltage attained in a given electrical alternating current. By controlling the energy of the x-ray beam, kVp controls the quality of the beam. Other factor which is mAs means the rate of flow of electrons for a preselected time. The mAs also mean mA* time (seconds). We can arrive at specific mAs value with various combinations of mA and s.

The mAs control the number of electrons produced at the cathode and subsequently the number of x-rays produced at the anode. The mAs control the quantitative character of the exposure factor. Exposure factors influence and determine the quantity and quality of the x-ray beam. The exposure of subjects is part of their medical diagnosis or treatment.

The quality assurances of diagnostic x-ray are based on the Basic Safety Standard BSS and International Commission of Radiological Protection, the use of diagnostic reference levels (ICRP- Report, 1966). The aim of the present is to investigate some factors affecting on quality assurance of conventional x-ray such as reproducibility of tube voltage, dose output, time , X-ray tube efficiency Accuracy of kVp , mA , time, and check the focal spot size and half value layer.

1.2. Problem of Study:

One of the typical human diagnostic techniques is x-ray. The x-ray examination depends on the range of radiation given to the subject. The radiation from the x-ray depends primarily upon the x-ray tube current (mA) tube voltage (kVp) and exposure time (s). These parameters define the dosage. Explore and analyze the x-ray exposure time parameter level which help to diagnostic image quality and also has some hazardous health effects upon human exposure or the tissue which is being irradiated.

1.3. Objectives:

1.3.1. General objectives:

To determine the Accuracy of Exposure Factors (kV and mAs) to assurance quality in Conventional X-Ray Machines in Khartoum state.

1.3.2. Specific Objectives:

- To measure the Kv and mAs using Kv meter.
- To find the significant difference between sitting and measured Kv and mAs.
- To find the linear regression coefficient between sitting and measured Kv and mAs.

1.4. over view of the thesis:

This study falls into five chapters, Chapter one, which is an introduction, deals with theoretical frame work of the study and (Literature review). It presents the statement of the study problems, objectives of the study, chapter two deals with radiological physics and back ground. Chapter three deal with material and method, Chapter fours deals with results and discussions. Chapter five conclusion , recommendations and references.

Chapter two

Literature Review

2.1. Radiation:

The propagation of energy from a radiative source to another medium is termed radiation. This transmission of energy can take the form of particulate radiation or electromagnetic radiation (i.e., electromagnetic waves). The various forms of radiation originating from atoms, which include (among others) visible light, X-rays and g-rays, are grouped together under the terms “electromagnetic radiation” or “the electromagnetic Spectrum”. Radio waves, which have the longest wavelengths and thus the lowest frequencies and energies of the various types of electromagnetic radiation, are located at tone end of the electromagnetic spectrum, whereas X-rays and g-rays, which have the highest frequencies and energies, are situated at the other end of this spectrum. (James E. Martin,2006).

2.1.1. Photon:

If the smallest unit of an element is considered to be its atoms, the photon is the smallest unit of electromagnetic radiation. Photons have no mass.

2.1.2. Common features of electromagnetic radiation:

It propagates in a straight line, it travels at the speed of light (nearly 300,000 km/s), it transfers energy to the medium through which it passes, and the amount of energy transferred correlates positively with the frequency and negatively with the wavelength of the radiation.

The energy of the radiation decreases as it passes through a material, due to absorption and scattering, and this decrease in energy is negatively correlated with the square of the distance traveled through the material.

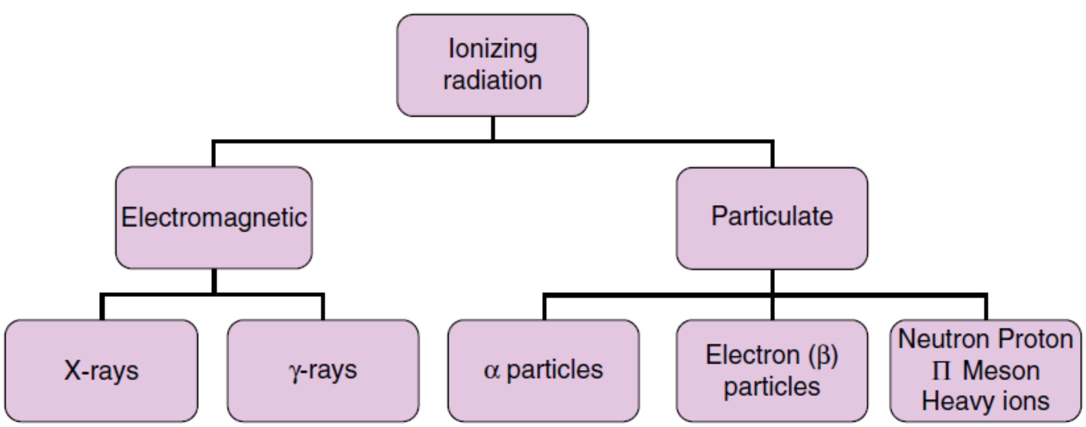
Electromagnetic radiation can also be subdivided into ionizing and non ionizing radiations. Non ionizing radiations have wavelengths of $^{3}10-7$ m. Non ionizing radiations have energies of <12 electron volts (eV); 12 eV is considered to be the lowest energy that an ionizing radiation can possess. (James E. Martin,2006).

2.1.3. Types of non ionizing electromagnetic radiation:

- Radio waves
- Microwaves
- Infrared light
- Visible light
- Ultraviolet light

2.2. Ionizing Radiation:

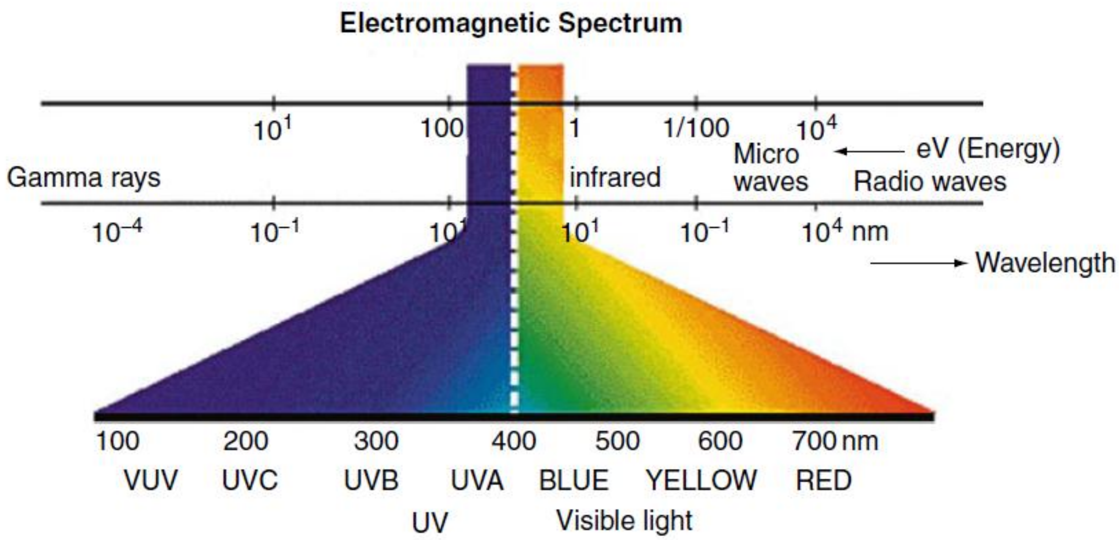
Ionizing (high-energy) radiation has the ability to remove electrons from atoms; i.e., to ionize the atoms. Ionizing radiation can be electromagnetic or particulate radiation. Clinical radiation oncology uses photons (electromagnetic) and electrons or (rarely) protons or neutrons (all three of which are particulate) as radiation in the treatment of malignancies and some benign conditions. (Murat, 2010).



The figure (2.1) show the types of ionizing radiation. (Murat, 2010).

2.3. Electromagnetic Spectrum:

The electromagnetic spectrum comprises all types of electromagnetic radiation, ranging from radio waves (low energy, long wavelength, low frequency) to ionizing radiations (High energy, short wavelength, high frequency). (James E. Martin,2006).



The figure (2.2) shows the electromagnetic spectrum. (James E. Martin, 2006).

Electrons are knocked out of their atomic and molecular orbits (a process known as ionization) when high-energy radiation interacts with matter. Those electrons produce secondary electrons during their passage through the material. A mean of energy of 33.85 eV is transferred during the ionization process, which in atomic and molecular terms is a highly significant amount of energy. When high-energy photons are used clinically, the resulting secondary electrons, which have an average energy of 60 eV per destructive event, are transferred to cellular molecules.

2.4. X-Rays:

X-rays were discovered by the German physicist Wilhelm Conrad Roentgen where The hot cathode Roentgen tube, which was developed by William David Coolidge in 1913, is a pressured (to 10−3 mmHg) glass tube consisting of anode and cathode layers between which a high-energy (106 –108 V) potential is applied. Electrons produced by thermionic emission in the cathode are accelerated towards the anode by the potential. (James E. Martin,2006).

2.4.1. Production of X-rays:

Roentgen was able to describe most of the known characteristics of x-rays after his monumental discovery by conducting several experiments; however, it was not possible to explain how x-rays were produced until the concepts of atoms, particles, and quanta were understood. It is now known that x-ray production occurs, as shown in Figure (2.3), when a negatively charged electron of kinetic energy eV enters the force field of the positively charged nucleus of a target atom. This force field, which is strongest for high-Z materials like tungsten, deflects and accelerates the electron, which causes the emission of electromagnetic radiation as it is bent near the nucleus. This is consistent with classical electromagnetic theory because the electron is not bound. Because radiation is emitted and energy is lost in the process, the electron must slow down, so that when it escapes the force field of the nucleus it has less energy. Overall, the electron experiences a net deceleration, and its energy after being decelerated is eV – hv where hm appears as electromagnetic radiation. Roentgen named these radiations x-rays to characterize their unknown status. (James E. Martin,2006)

This process of radiation being produced by an overall net deceleration of the electrons is called Bremsstrahlung, a German word meaning braking radiation.

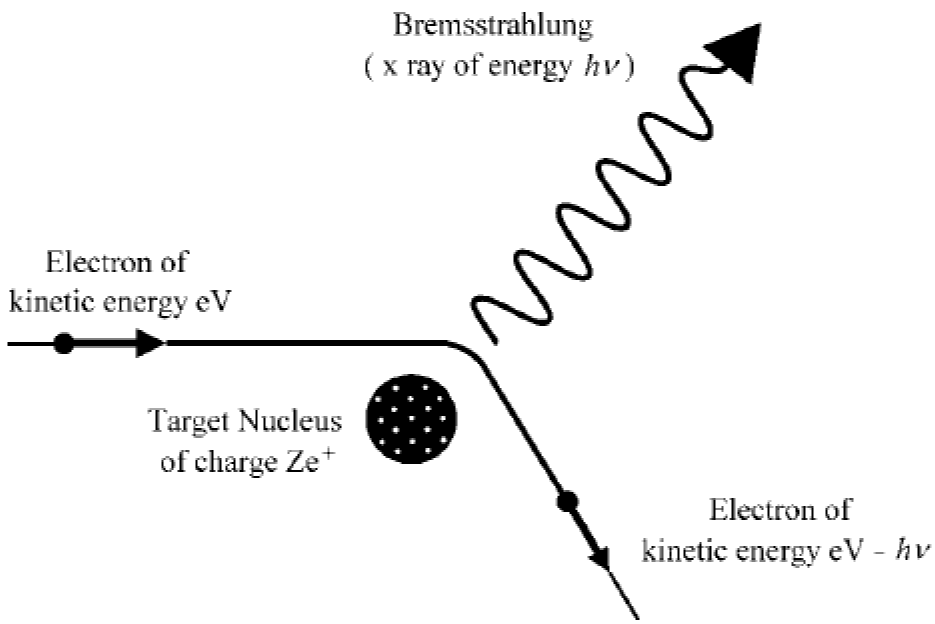


Figure (2.3) show the Production of x-rays in which accelerated electrons emit bremsstrahlung. (James E. Martin,2006).

2.4.2. Characteristic X-rays:

Figure (2.4) shows discrete lines superimposed on the continuous x-ray spectrum for molybdenum target because the 35 keV electrons can overcome the 20 keV binding energy of inner shell electrons in the molybdenum target. However, this does not occur for the tungsten target spectrum because the inner shell electrons of tungsten are tightly bound at 69.5 keV. The vacancy created by a dislodged orbital electron can be filled by an outer shell (or free) electron changing its energy state, or, as Bohr described it, jumping to a lower potential energy state with the emission of electromagnetic radiation; the emitted energy is just the difference between the binding energy of the shell being filled and that of the shell from whence it came. And since the electrons in each element have unique energy states, these emissions of electromagnetic radiation are "characteristic" of the element, hence the term "characteristic x-rays". They uniquely identify each element. (James E. Martin,2006).

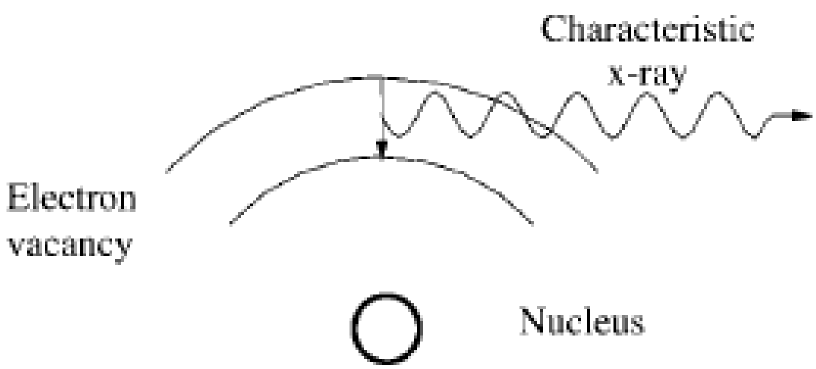


Figure (2.4) show the Emission of a characteristic x-ray due to a higher energy electron giving up energy to fill a particular shell vacancy.

2.4.3. The X-Ray Tube:

Figure (2.5) is a schematic representation of a conventional x-ray tube. The tube consists of a glass envelope that has been evacuated to high vacuum. At one end is a cathode (negative electrode) and at the other an anode (positive electrode), both hermetically sealed in the tube. The cathode is a tungsten filament that when heated emits electrons, a phenomenon known as *thermionic emission*. The anode consists of a thick copper rod at the end of which is placed a small piece of tungsten target. When a high voltage is applied between the anode and the cathode, the electrons emitted from the filament are accelerated toward the anode and achieve high velocities before striking the target. The x-rays are produced by the sudden deflection or acceleration of the electron caused by the attractive force of the tungsten nucleus. The x-ray beam emerges through a thin glass window in the tube envelope. In some tubes, thin beryllium windows are used to reduce inherent filtration of the x-ray beam. (James E. Martin,2006).

2.4.3.1. The Anode:

The choice of tungsten as the target material in conventional x-ray tubes is based on the criteria that the target must have high atomic number and high melting point. The efficiency of x-ray production depends on the atomic number, and for that reason, tungsten with $Z = 74$ is a good target material. In addition, tungsten, which has a melting point of 3,370°C, is the element of choice for withstanding intense heat produced in the target by the electronic bombardment. Efficient removal of heat from the target is an important requirement for the anode design. This has been achieved in some tubes by conduction of heat through a thick copper anode to the outside of the tube where it is cooled by oil, water, or air. Rotating anodes have also been used in diagnostic x-rays to reduce the temperature of the target at any one spot. The heat generated in the rotating anode is radiated to the oil reservoir surrounding the tube. It should be mentioned that the function of the oil bath surrounding an x-ray tube is to insulate the tube housing from high voltage applied to the tube as well as absorb heat from the anode. (James E. Martin,2006).

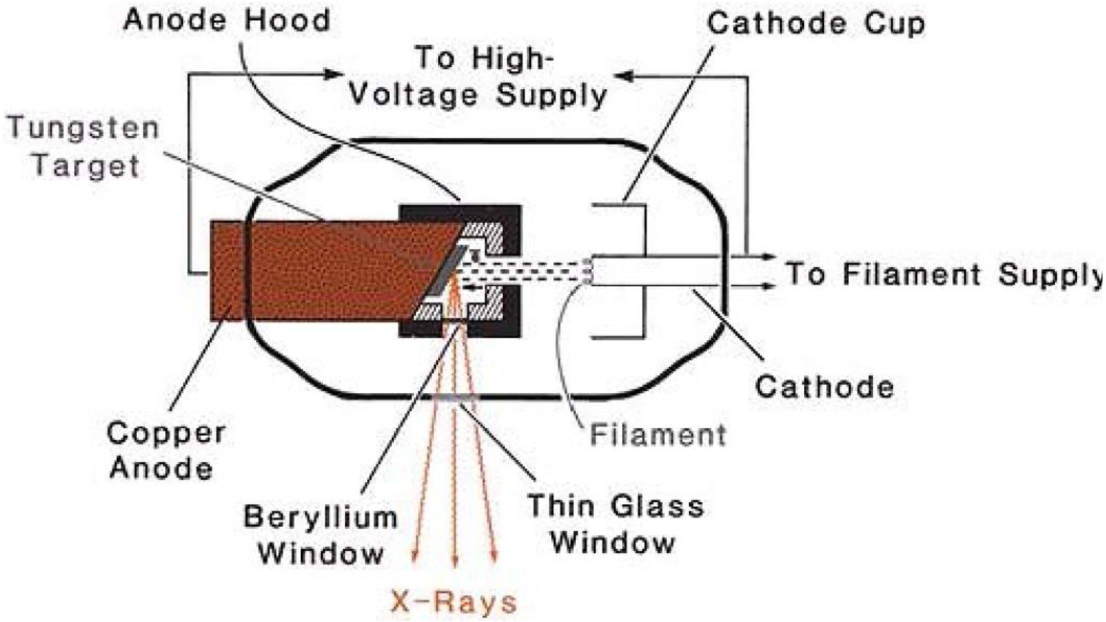


Figure (2.5) show the schematic representation of a conventional x-ray tube.

2.4.3.2. The Cathode:

The cathode assembly in a modern x-ray tube (Coolidge tube) consists of a wire filament, a circuit to provide filament current, and a negatively charged focusing cup. The function of the cathode cup is to direct the electrons toward the anode so that they strike the target in a well-defined area, the focal spot. Since the size of the focal spot depends on filament size, the diagnostic tubes usually have two separate filaments to provide "dual focus," namely one small and one large focal spot. The material of the filament is tungsten, which is chosen because of its high melting point. (James E. Martin,2006).

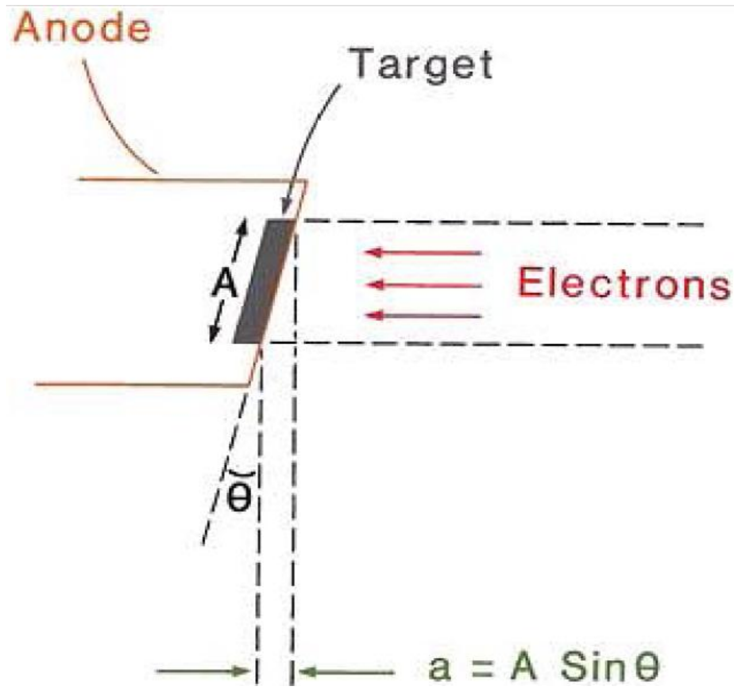


Figure (2.6) show the illustrating the principle of line focus. (James E. Martin,2006).

2.5. The Interaction of Radiation with Matter:

Radiation is scattered and absorbed when it passes through tissue. The intensities of mono energetic X-rays or gamma rays attenuate exponentially within tissues. In other words, the intensity of radiation constantly decreases as it propagates within tissues. This decrease depends on the type of tissue and its thickness. If the wave length stays constant, the intensity of the radiation passing through a tissue can be calculated by the following formula:

$$I = I_0.e^{-\mu t}$$

I = intensity of outgoing radiation beam

*I*0 = intensity of incoming radiation beam

m = absorption coefficient (which is positively correlated with the fourth power of the atomic number of the penetrated tissue, and the third power of the wavelength of the radiation)

t = tissue thickness

As seen in the above formula, the intensity of the radiation decreases exponentially with the absorbent thickness, and the intensity of the outgoing radiation depends on the tissue absorption coefficient and its thickness. the five types of interaction of radiation with matter shown below:

2.5.1. Photoelectric Effect:

This phenomenon, which was theorized by Albert Einstein in 1905, was actually first observed by Heinrich Rudolf Hertz in 1887, and was therefore also known as the Hertz effect. To define it simply, when any electromagnetic radiation reaches a surface (generally a metallic surface), it transfers its energy to the electrons of that surface, which are then scattered. At the atomic level, the incoming radiation knocks an electron from an inner atomic orbital, propelling it from the atom as shown in the figure (2.7). (James E. Martin,2006).

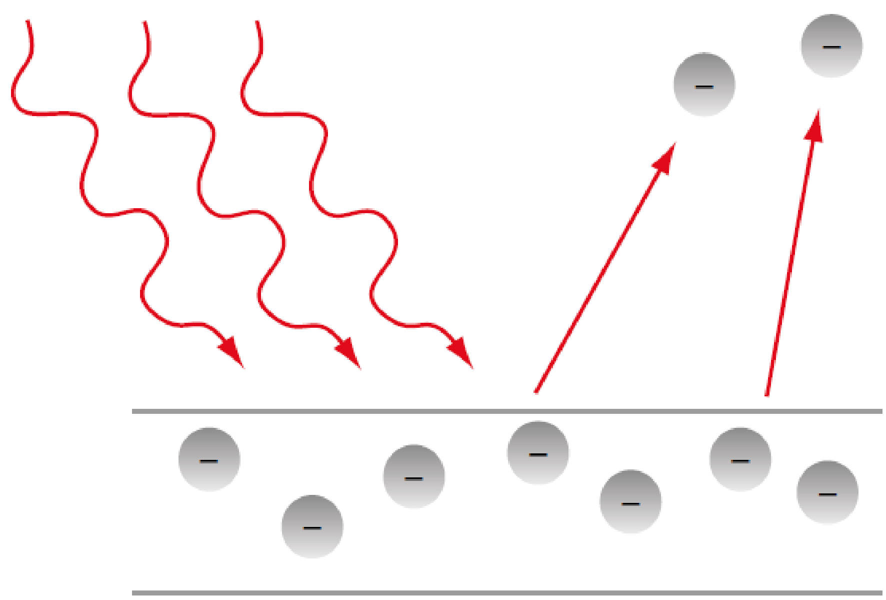
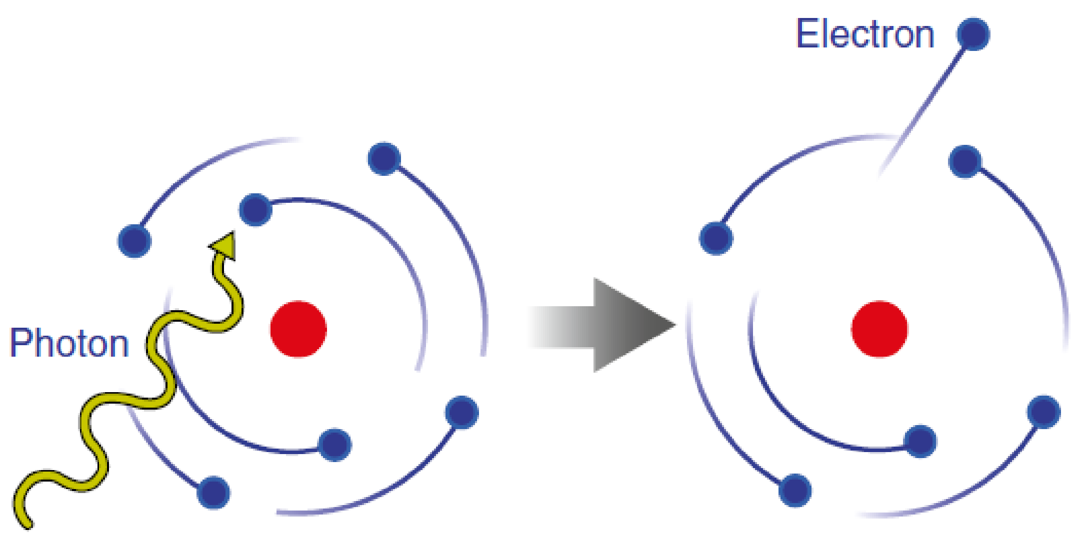


Figure (2.7) show the Photoelectric effect. (Murat, 2010).

This is the basic interaction in diagnostic radiology.

It is dominant at energies of less than 35 kV, and in atoms with high atomic numbers (*Z*). Since the atomic number of bone is higher than that of soft tissue, bone absorbs more radiation than soft tissue. This absorption difference is the basis of diagnostic radiology. This effect also explains why metals with high atomic numbers (e.g., lead) are used to absorb low-energy X-rays and gamma rays.



The Figure (2.8) shows the illustration of photoelectric effect. (Murat, 2010).

2.5.2. Compton Effect:

In the Compton Effect, a photon collides with an electron in an outer orbital, and the photon and electron are scattered in different directions (where q is the angle between the directions) The energy of the incoming photon is transferred to the electron in the form of kinetic energy. The scattered electron also interacts with the outer orbital electrons of other atoms. (Murat, 2010).

After the interaction, the photon has a lower energy than it did beforehand.

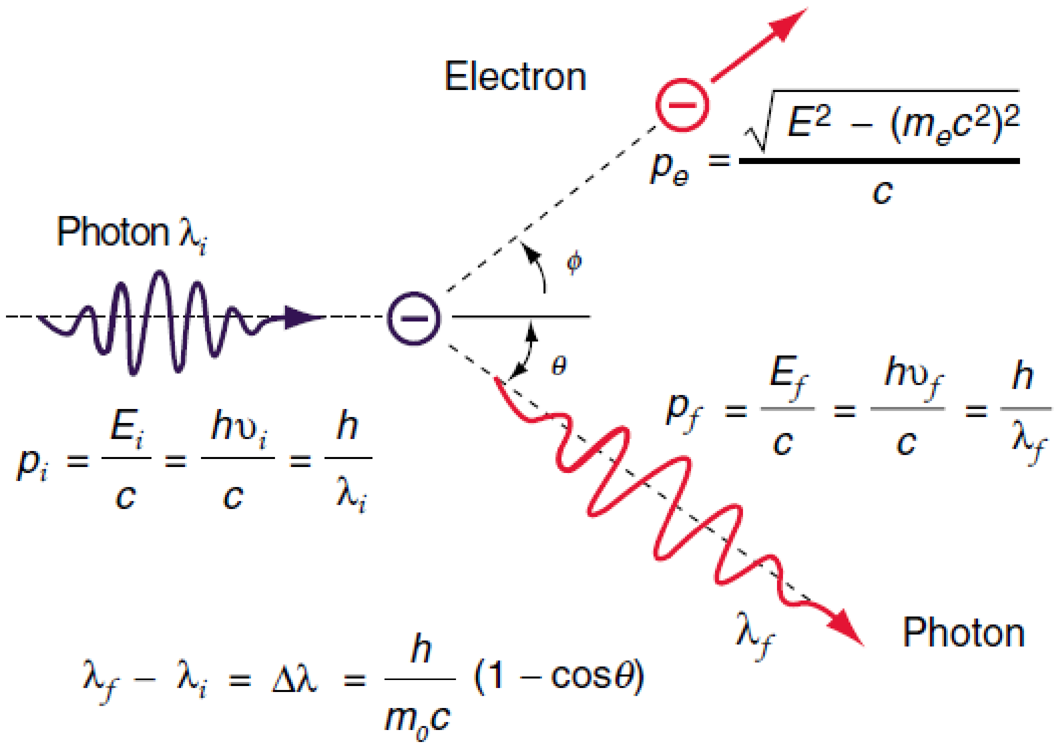
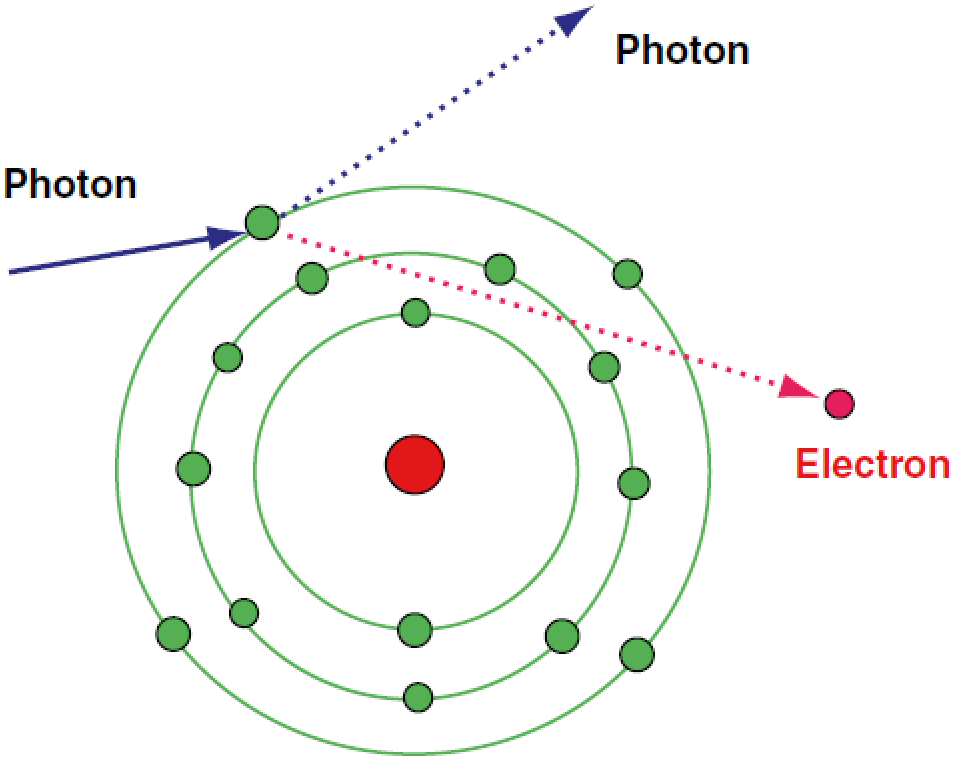


Figure (2.9) show the Math associated with the Compton Effect. (Murat, 2010).

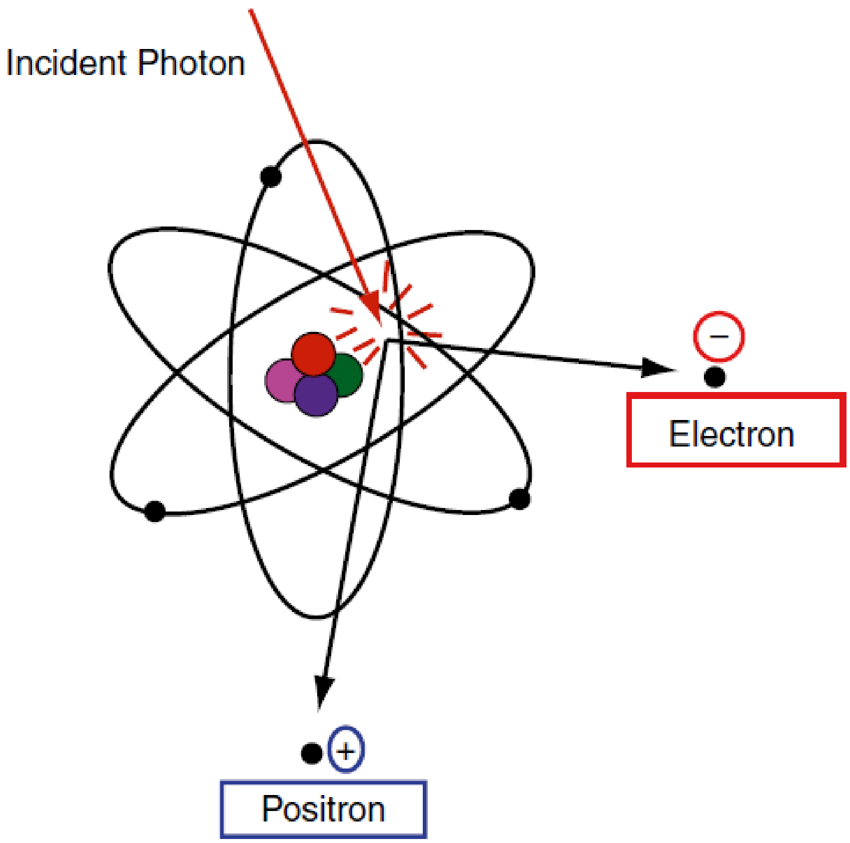
This is the main mechanism for the absorption of ionizing radiation in radiotherapy. It is the dominant effect across a wide spectrum of energies, such as 35 kV–50 MV. It has no dependency on the atomic number (*Z*) of the absorbent material, but it does depend on the electron density of the material. The absorption of incoming radiation is the same for bone and soft tissues.



The Figure (2.10) shows The illustration of Compton Effect. (Murat, 2010).

2.5.3. Pair Production:

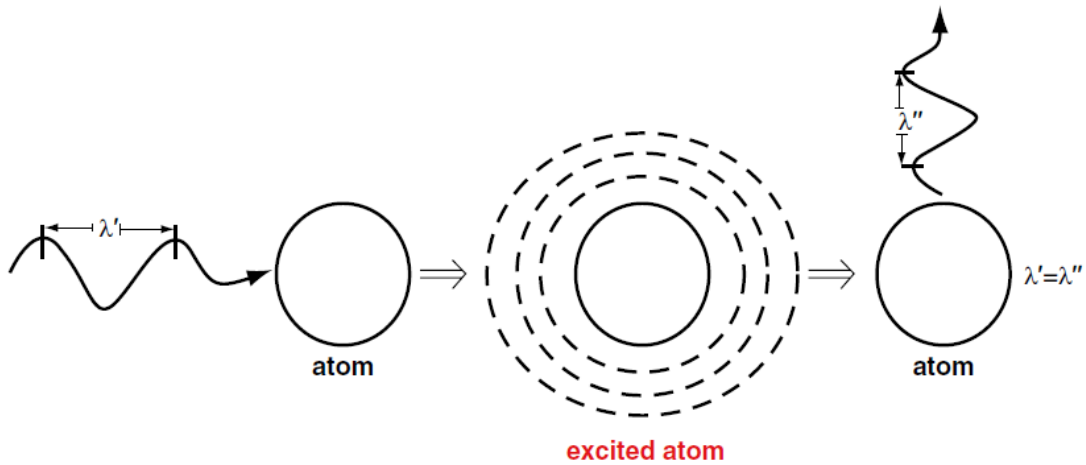
This is a relatively rare effect. In it, a photon transforms into an electron and a positron near a nucleus (Figure 2.11). The electron sheds all of its energy by the absorption processes explained above. On the other hand, the positron propagates through the medium ionizing atoms until its energy has dropped to such a low level that it pulls a free electron close enough to combine with it, in a process called annihilation. This annihilation causes the appearance of a pair of photon moving in opposite directions, and each with 0.511 MeV of energy. These annihilation photons are absorbed through either photoelectric or Compton events.



The Figure (2.11) shows the illustration of Pair production. (Murat, 2010).

2.5.4. Coherent Effect (Rayleigh scattering):

Here, an electron is scattered when an electromagnetic wave or photon passes close to it. This type of scattering is explained by the waveform of the electromagnetic radiation. There are two types of coherent scattering: Thomson scattering and Rayleigh scattering. The wave/photon only interacts with one electron in Thomson scattering, while it interacts with all of the electrons of the atom in Rayleigh scattering. In Rayleigh scattering, low-energy radiation interacts with an electron, causing it to vibrate at its own frequency. Since the vibrating electron accelerates, the atom emits radiation and returns to its steady state. Thus, there is no overall transfer of energy to the atom in this event, so ionization does not occur. The probability of coherent scattering is high in heavy (i.e., high-*Z*) matter and for low-energy photons. (Murat, 2010).



The Figure (2.12) shows the illustration of Rayleigh scattering. (Murat, 2010).

2.6. Kilovoltage Effective on exposure:

kVp has the greatest effect on the radiographic image when all other factors remain constant. Because kVp is the factor that gives the rays their penetrating quality, it directly influences the quality of radiation reaching the film. This, in turn, determines the radiographic contrast and density. Kilovolt age is a major agent in the production of SR that must be controlled to prevent fogging on the film. Use of low kVp may result in images deficient in details; injudicious use of high kVp may result in fogged or high-density images in which details are obscured by excessive silver deposits and a degradation of contrast.

kVp also has a limited effect on quantity of radiation. Because changing kVp varies the speed of the electrons, and therefore, the wavelength of radiation, an increase of kVp gives a corresponding increase in the number of diagnostic photons. Even though the major attribute of kVp is the variation in penetrating power kVp does affect, to a smaller degree, the quantity.

2.6.1. Kilovoltege and exposure latitude:

Exposure latitude varies with the kVp applied and is the range between minimum and maximum kVp that will produce a diagnostically acceptable scale of translucent densities. Exposure latitude is an important element in any standardized exposure system. Since "correct exposure" may be anyone within a fairly wide range if the kVp is adequate for thorough penetration, use of an optimum kVp is more likely to produce greater uniformity of radiographic results than would the use of relatively low variable kVp. A general rule is the longer the scale of radiographic contrast, the greater is the exposure latitude.

2.6.2. Influence of Kilovoltage:

The characteristics of primary radiation can be changed by kVp, with control of SR fog and favorable image quality. With the increase of kVp, the quantity of fog produced reaches a point where it exceeds many times the density produced by remnant radiation. This means that the desired image may be almost completely hidden because of the fog. The more the image is veiled by fog, the less detail is affected by factors that would normally alter it.

2.6.3. Over exposure:

When greater than necessary kVp is used, the overall density appears high with SR fog. The contrast scale is degraded and detail is obscured. Usually, a reduction of 10 to 20 kVp will correct the appearance. It may be necessary to adjust the mAs factor slightly. To avoid overexposure due to kVp.

2.6.4. Under exposure:

Use of inadequate kVp is characterized by blank, transparent areas without silver deposit and other areas having high densities--few intermediate tones of density are present. An increase of 15 to 20 kVp will usually produce sufficient penetrating radiation to obtain the necessary detail, provided the mAs is also adjusted.

2.6.5. Relation of kVp-mAs-SID-Density:

Radiographic density is not only influenced by kVp but it also varies with the mAs and SID used. In medical radiography, there is no simple mathematical method for determining kVp-mAs density ratios. Such factors as the thickness and density of the body tissues to be examined, the characteristics of the x-ray apparatus, and if the film is used with or without intensifying screens exert pertinent influences. Fairly close approximations between kVp and other exposure factors have been of necessity established by experience--by trial and error. There are two procedures that may be followed: one is used in determining the approximate change in mAs required to compensate for a change in kVp, the other in determining the change in kVp required for a given mAs change. Changing the kVp or mAs and keeping the density constant requires complex mathematical manipulations.

2.7. Parameters of x-ray:

In radiography, dose and image quality are dependent on radiographic parameters, dose optimization for the Quality Control Tests of X-Ray Equipment effect on patient dose and image quality.

2.7.1. Absorbed dose

Absorbed dose is the quantity that expresses the radiation concentration delivered to a point, such as the entrance surface of patient's body. Absorbed dose in air is recognized as air kerma and it is a measure of the amount of radiation energy, in the unit of joules (J), actually deposited in or absorbed in a unit mass (kg) of air. Therefore, the quantity, kerma,

is expressed in the units of J/kg which is also the radiation unit, the gray (G) (Sprawls, 1987;Hendee et al., 1984).

2.7.2. kVp:

The high energy of the x-ray spectrum is determined by the kilovoltage applied to the x-ray tube. The maximum photon energy is numerically equal to the maximum applied potential in kilovolts. The maximum photon energy is determined by the voltage during the exposure time. This value is generally referred as the kilovolt peak (kVp) and is one of the adjustable factors of x-ray equipment (Sprawls, 1987).

2.7.3. mAs:

The x-ray cathode is heated electrically by a current from a separate low voltage power supply. The output of this supply is controlled by the mA selector on the x-ray unit. Additionally, the duration of the x-ray exposure is controlled by the time selector. mAs is described by multiplying of these two values (mA x second) (Hendee et al., 1984).

2.7.4. Half Value Layer (HVL)

Half value layer describes both the penetrating ability of specific radiations and the penetration through specific objects. HVL is the thickness of material that reduces the intensity of an x-ray beam by half, and is expressed in unit of distance (mm) (Sprawls, 1987).

2.7.5. Image quality

The purpose of the radiographic image is to provide information about the medical condition of the patient. A quality image is one that provides all the information required for diagnosis of the patient’s condition (Hendee et al., 1984).

Image quality is not a single factor but is described with beam alignment, collimation alignment, contrast and resolution. Contrast means differences in the form of gray scales or light intensities, whereas the resolution is a measure of its ability to differentiate between two objects a small distance apart; such that they appear distinct from one another.

An image is acceptable as qualified only if it has high resolution and high contrast.

2.8. Measurement of X-ray tube Output and exposure time product

X-ray tube output is the amount of exposure, in millirontgens (mR) delivered to a point in the centre of the useful X-ray beam at a distance of 1 meter from the focal spot for 1 mAs of electron passing through the tube. The output expresses the ability of the tube to convert electronic energy into X-ray exposure. X-ray tube output is the single most important parameter to quantify radiation yield (Zoetelief et al, 2006). The free-in-air exposure, FAE (mR) was measured using factory calibrated KV meter (US made Victoreen X-ray test device, model 4000 M+) obtained from the Department of Physics (DOP) University of Ibadan. The consistency of X-ray tube output with the tube current (mA) or tube current exposure-time product (mAs) was measured for the range of mA or mAs values used in practice. The detector (KV meter) measures the mean, effective and maximum peak tube voltage, power phase, exposure and exposure time. This system determines the tube voltage with accuracy of ± 2% (Victoreen, 1995). The internal ionization chamber that measures exposure has volume of 36 cm3. The exposure time is measured to an accuracy of ± 2%. The FAE (mR) measured is converted into output in mGy (mAs)-1 by multiplying by a factor 0.00877/ mAs (Chang Jong and Hui- Yu, 1999) where mAs in the denominator is the product of the tube current and exposure time set at the time of measurement of the output.

2.9. Quality control and dose optimization:

Radiation is a major risk in diagnostic and therapeutic medical imaging. The problem is caused from incorrect use of radiography equipment and from the radiation exposure to patients much more than required. Exposure of different dose values for the same clinical examination is an enough reason to draw attention to this issue. International Commission on Radiation Protection (ICRP), the International Atomic Energy Agency (IAEA) and other various independent institutions has been making publications in relation to ionizing radiation protection for more than fifty years. Report 60 of the ICRP and the Basic Safety Standards that was published in the IAEA report have three basic principles related to the radiation protection (ICRP, 1991; IAEA, 1996).

The most important issue in these principles is the optimization of radiation. In the mentioned policy, the lowest dose is aimed by considering the country's economic and social factors for acceptable applications. Personnel already receive low dose with protection systems in the working areas. However, the patient doses must be taken under control based on the principle of optimization as much as possible.

There are two important points when performing a radiological procedure:

- To obtain the best possible image for a clear diagnosis of the disease,
- To apply the lowest dose for protecting the patient while getting the best image.

The second point indicates that the patient’s radiation dose level must be kept at the lowest possible dose. In other words, it indicates dose optimization. The dose optimization meaning "the minimum radiation dose of the optimum image quality", is achieved by applying quality control procedures, calibration and dosimetric measurements. In the Radiology Quality Control systems, the biggest problem is dose control and dose optimization. Neither patient nor users knows how much dose is exposed because there is no any system in the x-ray device for measuring or showing dose during exposure. Since there is no dose adjustment on

the equipment, the systems are operated by using the usual parameters; kVp and mAs. Because dose cannot be adjusted, the patient may receive
more dose than the aimed dose.

For dose optimization, all exposures should be kept at the minimum dose level in according to the ALARA principle (ALARA-as low as reasonably achievable). The aim of the optimization is not to download the risks of irradiation to zero. It is to reduce them to an acceptable level. This can be possible only by examining all parameters that affect the X-ray, by investigating the relationship between dose and these parameters, on the basis of this relationship, by performing the necessary regulations.

In all x-ray equipment, the operator can control the quantity and the quality of the radiation with kVp and mAs controls. If the equipment is not properly controlled, it will not be possible to control the radiation output. For this reason, optimization consists of not only improving of image quality and low dose but also establishing quality assurance and quality control programmes to ensure a proper performance of the x-ray equipment.

As frequently documented in the scientific literature, patient dose and image quality are basic aspects of any quality control (QC) tests in diagnostic radiology. Image quality must be adequate for diagnosis and it must be obtained with low doses.

The following QC tests are performed for both patient dose and image quality evaluation;

- kVp Accuracy and Repeatability
- Dose-kVp Linearity Test
- Dose-mAs Linearity Test
- X-ray Tube Output-kVp Relation
- HVL (Half Value Layer)

 Image Quality (Beam alignment, collimation alignment, contrast and resolution)

The quality control tests' methods, as well as the criteria for scoring the results, are in full agreement with those specified in the American Association of Physicists in Medicine. (AAPM, 1981; IEC 61223-3-1, 1999).

2.10. Consistency of radiation output using a digital kv meter:

2.10.1. Equipment:

Digital radiation output meter rule.

2.10.2. Procedure:

1. Place the radiation output meter on the tabletop with the detector facing the x-ray tube.
2. Position the x-ray tube at a standard distance from the cassette such as 100 cm.
3. Center the tube accurately to the sensor area and collimate the beam to its edges.
4. Switch on the output meter and allow it to warm up. Ensure it is working correctly.
5. Set the same exposure each time the test is carried out e.g. 70 KVP .20 MAS, referring to the operating instruction of digital meter for correct exposure conditions.
6. Make exposure.
7. Record reading on display. Repeat the exposure twice (to check the consistency).
8. Record the three readings on the result sheet. (Philip, 1991).

2.10.3. Assessment and evaluation:

From the sample result, if any of the result differ by more than 10% from the mean, further test should be carried out to check for a fault condition. (BIRL, 1988)

2.11. Consistency of radiation at different MA setting using a digital meter:

2.11.1. Purpose of test:

This test is used to check the consistency of radiation output at different MA settings when using the same KV and MAS throughout the test. The measurements are made using a digital exposure meter.

2.11.2. Procedure:

1. Place the radiation output meter on the tabletop with the detector facing the x-ray tube.
2. Position the x-ray tube at a standard distance such as 100 cm.
3. Center the x-ray tube accurately over the sensor area and collimate the beam to its edges.
4. Switch on the output meter and allow it to worm up. Ensure it is working correctly.
5. Work out the exposure factor to be used e.g. 70KVP /100MA /0.2 s 70KVP /200MA /0.1s 70KVP/400MA/0.05s 70KVP/500MA/0.5s
70KVP/500MA/0.4s
6. Make an exposure on each of the settings and repeat twice more to check the constancy.

7. Record the average of three readings on the result sheet in any of three reading obtained varies more than 10% from the mean, the test should be carried out to check for faults in the equipment. (Philip, 1991)

2.11.3. Assessment and evaluation:

From the simple results sheet inconsistent may be caused by a fault in the space charge compensation circuit or in accuracy of the timer, kvp compensation or timer synchronization engineer should be consulted. (Philip, 1991)

2.12. Assessment of kilovotage applied to the x-ray tube using digital meter:

2.12.1. Purpose of test:

A digital KVP meter is used to compare the effective kilovotage applied to an x-ray tube with that selected at the control panel.

2.12.2. Equipment:

KV meter and Meter rule.

2.12.3. Procedure:

1. Read the operating instructions supplied with the KVP meter and carry out the test following these instructions. It is important that Kvp limits and requirements relating to MA time and distance set out in the operating instructions are followed.
2. Remember to check the battery in the meter to ensure that it does not need changing.
3. Ensure that the meter is placed on a flat surface, perpendicular to the reference axis of the x-ray beam, and center the detector collimate as necessary.
4. Repeat the test three times for each Kvp tested to check for consistency.
5. Record the average of the three reading on the result sheet.

2.12.4. Assessment and evaluation:

If any results vary more than 10% from the baseline, contact the service engineer (Philip, 1991).

2.13. Accuracy of exposure timer using digital timer meter:

2.13.1. Purpose:

This test is used to check the accuracy of the exposure timer using a digital meter.

2.13.2. Equipment required:

Digital timer meter and Meter rule.

2.13.3. Method:

1. Place the digital timer meter on the tabletop with the detector facing the x-ray tube.
2. Position the x-ray tube at a standard distance from the cassette such as 100 cm.
3. Center the tube to the sensor area and collimate the beam to its edges.
4. Switch on the timer meter ensuring that it is in the correct phase setting for the equipment to be tested.
5. Set the same exposure each time the test is carried out e.g. 70 kvp,100 MA .04s.
6. Make an exposure.
7. Record reading on display. Repeat the exposure twice more to check the consistency.
8. Record the average of the three readings on the result sheet.

2.13.4. Assessment and evaluation:

If any of the results vary either by more than 10% or one pulse from the mean, further tests should be carried out to check for a fault condition. (Philip, 1991).

2.14. Previous studies:

T.M.Taha, 2010, Study the Quality Assurance of Conventional X-ray Machines Using Non invasive KV meter the study aimed to investigate some factors affecting on quality assurance of conventional x-ray such as reproducibility of tube voltage, dose output, time, and x-ray tube efficiency, Accuracy of kVp, mA, time, and focal spot size. And half value layer. Examinations of these factors are studied using non invasive kV meter NeroMax 8000 which connected with suitable ionization chambers. The quality assurance tests of X-ray diagnostic examination are measured and compared with the international tolerance. to detector distance 66 cm. The dose output was measured using Nero mAX -8000 The dose output was measured with different thickness. The thickness which gave half of zero doses is considered as the half value thickness. It is the thickness of some standard material required to reduce the intensity of a beam to one half its original value The quality assurance procedures of x-ray equipment were carried out for six machines of the same type and manufacture . .NeromAx 8000 has been used to check the quality assurance of xray machine. The NERO Max consists of the control console, detector cable, two filter cards, ma's leads, Excel Add-in, AC adapter, and HVL plates; the compact control console houses the rechargeable battery, supper bright easy to read backlit display, eight control buttons, and the sophisticated electronic necessary for accurate, reproducible measurements. Connectors or power input , RS-232, printer, scope output and the NERO mix detector contains sensors for simultaneously measuring KV, exposure or rate and am or mass. Solid state detectors are used to measure KV, An ion chamber, located in the top of the detector, is used for exposure / rate measurements. The filter cards contain the various filters needed to accurately measure kilo voltage. Each filter card is coded so that the NERO mAx " knows " which filter is in use and its position. Reproducibility of dose output was ranged from 0.1 to 0.7 %, of time was ranged from 0.01 to 3 % and of high voltage was ranged from 0.1% to 0.7% which is lower than the tolerance ;limit The efficiency of the x-ray tubes were ranged from 62% to 80% which were greater than 25 μGy/mAs for 1 m FDD, Focus to Detector Distance and at 80 kV tube voltage KV accuracy for different settings of six x-ay machines voltage was examined by setting the source to detector distance at 66 cm of exposure, time at 0.1 sec for different KV intervals from 50-120 KV . KV accuracy is good at all KVp stations for six machine except one of the examined machines gave accuracy of 20 % which is higher than the tolerance limit.(± 5%). That mean this machine needs calibration. It recalibrated and adjusted to 5% KV accuracy. Time accuracy is good at all time settings stations for all examined machine which is lower than the tolerance limit. (± 10%).

Chapter Three

Materials and Methods

3.1Materials:

3.1.1. X-ray machines:

In the study, 10 different units of X-ray machines from different manufactures were included.

3.1.2. Kv Meter:

A digital KVP meter is used to check accuracy of kilovotage applied to an x-ray tube with that selected at the console and check the accuracy of the exposure output factors (Kv and mAs) using a digital meter.

3.2. Methods:

3.2.1. Study duration:

This study performed in period of May 2014 to February 2015.

3.2.2. Study place:

This study was conducted in Khartoum Teaching Hospital , Modern Medical Center, Omdurman Teaching Hospital, Bahry Teaching Hospital, Radiation and Isotope Center Khartoum, Alnelain Diagnostic Center, Sharg Alneel Hospital, Bestcare Hospital and Ibrahim Malik Teaching Hospital .

3.2.3. Method of data collection:

In the data collection the Kv meter was Placed on the tabletop with the Detectors facing the x-ray tube positioned at 1 meter of the focal spot of the X-ray tube and centered the tube accurately to the sensor area and collimate the beam to its edges, Switched on the Kv meter and allow it to warm up, ensure it is working correctly. Exposure factors Kv and mAs were sated from the console each time the test is carried out, referring to the operating instruction of digital meter for correct exposure conditions. And Recorded the reading on Kv meter display, for each kVp meter were made measurements in the range from 45kV to 85kV. The measurements were increased in steps of 5kV. For each selected X-ray equipment were take 9 measurements. Repeated the exposure 9 times and all readings were recorded on the result sheet.

Table (3.1) the Kvp and mAs accuracy test were performed with the following exposure factors for each units

Kvp	mAs
45	40
50	50
55	64
60	80
65	100
70	160
75	200
80	320
85	400

3.2.5. Method of data analysis:

The data will analyze with excel program

3.2.6. Method of data storage:

The data stored securely in password personal computer (PC).

Chapter Four

The Results

This study involved Accuracy of Exposure Factors for 10 x-ray equipment, the table and figures below show the KV and mAs accuracy of x-ray machines.

Table (4-1) show the setting and measured Kvp and mAs for machine (1).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	86.7	50	50.4
80	80.8	100	100.1
75	74.5	160	159.3
70	69	200	192.3
65	64	250	169.6
60	60.5	40	39.9
55	54.2	320	201.3
50	49.7	400	227
45	45	360	212.2

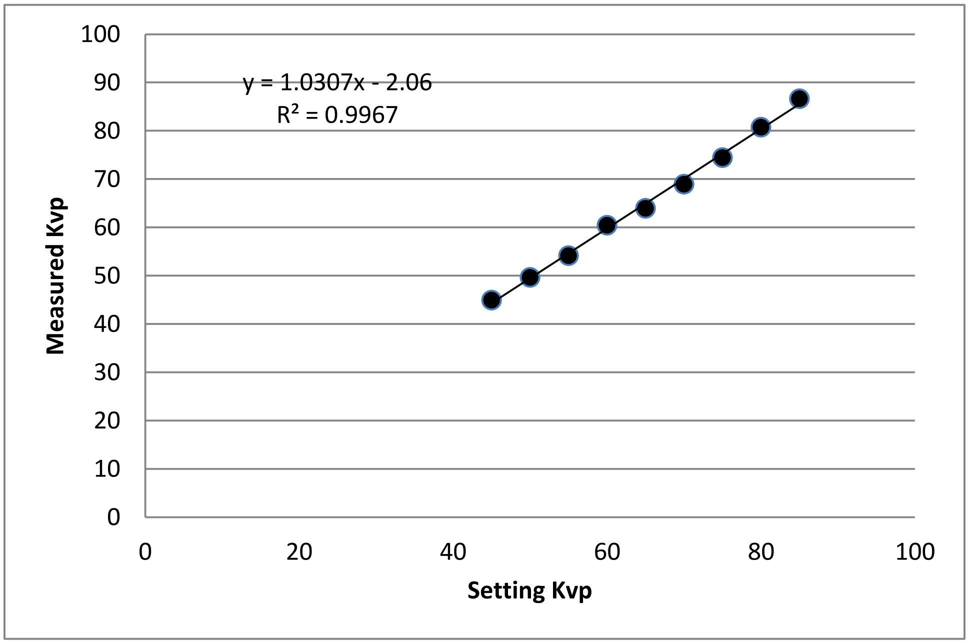


Figure (4-1) show the relationship between setting Kvp and measured Kvp for machine (1).

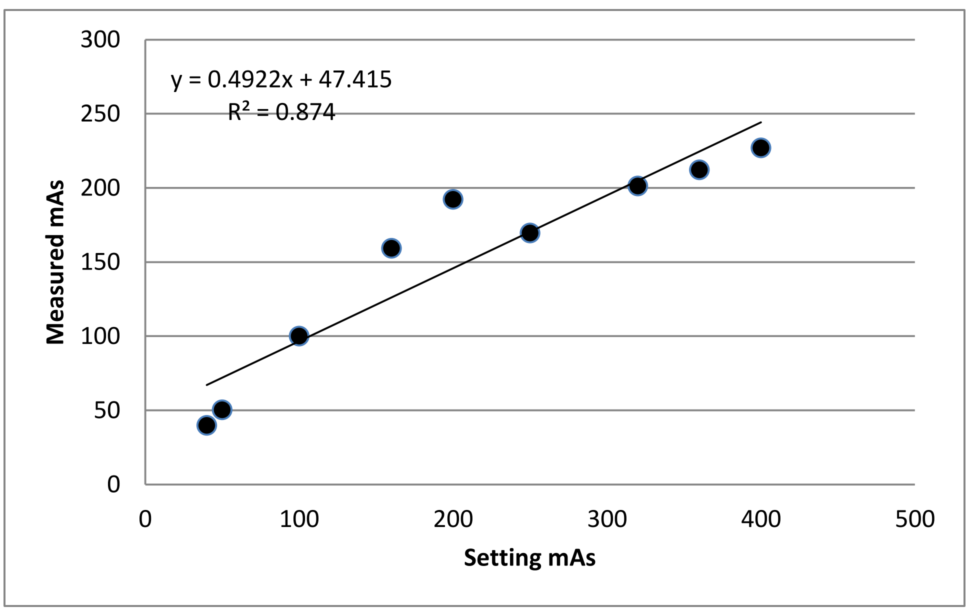


Figure (4-2) show the relationship between setting mAs and measured mAs for machine (1).

Table (4-2) show the setting and measured Kvp and mAs for machine (2).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	76.9	40	41.4
80	72.1	100	104.8
75	67.4	160	167.3
70	62.8	200	183.2
65	58.3	125	129.9
60	54	80	83.3
55	49.8	50	51.9
50	45.4	250	200.9
45	42.1	64	65.7

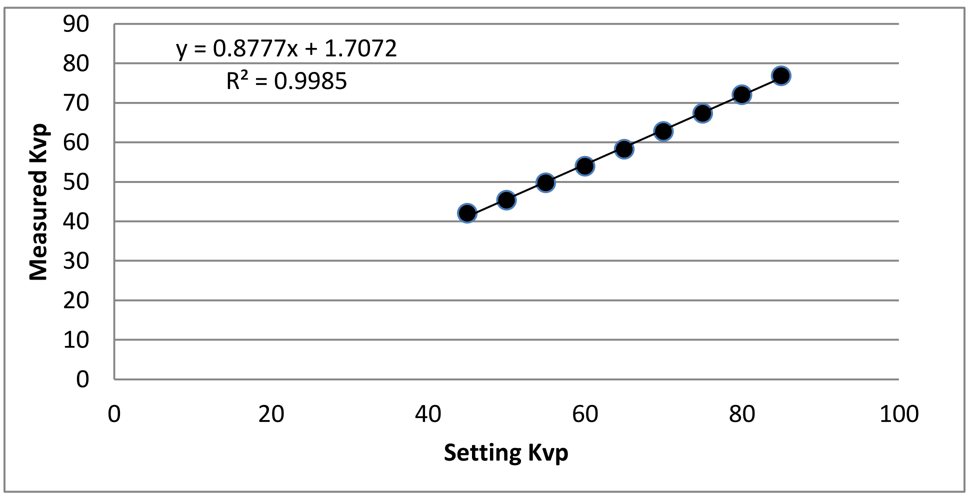


Figure (4-3) show the relationship between setting Kvp and measured Kvp for machine (2).

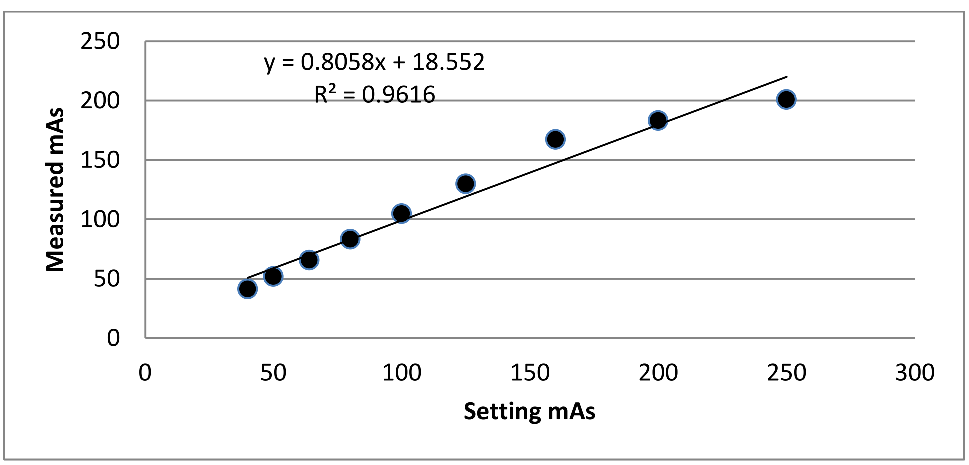


Figure (4-4) show the relationship between setting mAs and measured mAs for machine (2).

Table (4-3) show the setting and measured Kvp and mAs for machine (3).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	79.5	125	128.9
80	74.9	50	50.2
75	71.1	80	82.1
70	66.5	250	223
65	63	40	41.6
60	59.4	100	102.2
55	56.2	64	66.3
50	48.9	200	189.9
45	44.1	160	163.2

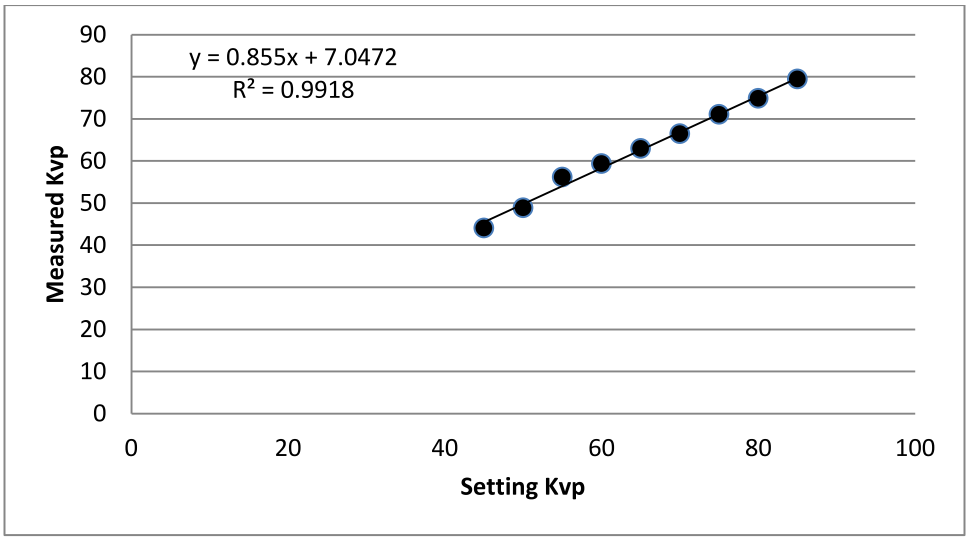


Figure (4-5) show the relationship between setting Kvp and measured Kvp for machine (3).

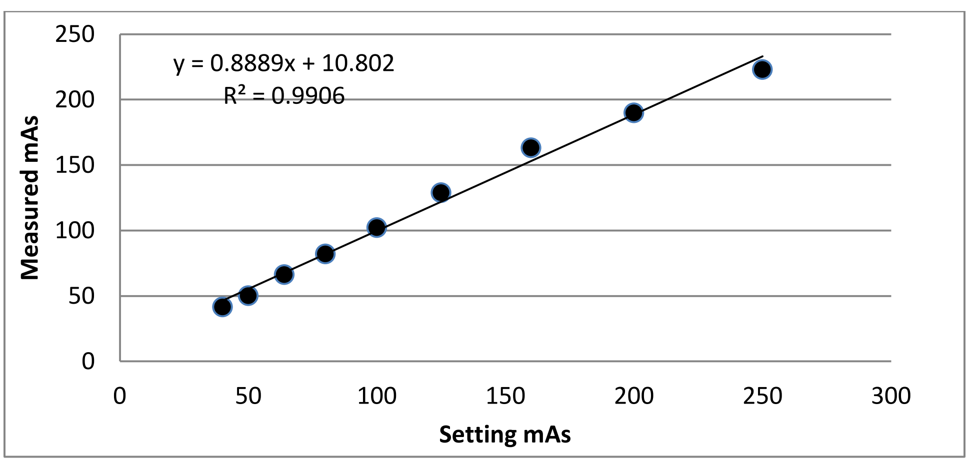


Figure (4-6) show the relationship between setting mAs and measured mAs for machine (3).

Table (4-4) show the setting and measured Kvp and mAs for machine (4).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	85.1	200	186.1
80	79.6	40	40.7
75	74.2	160	158.5
70	68.4	64	65.4
65	64	50	51.3
60	61.3	100	100.9
55	53	250	216.8
50	48.7	80	81.5
45	44.8	125	127.6

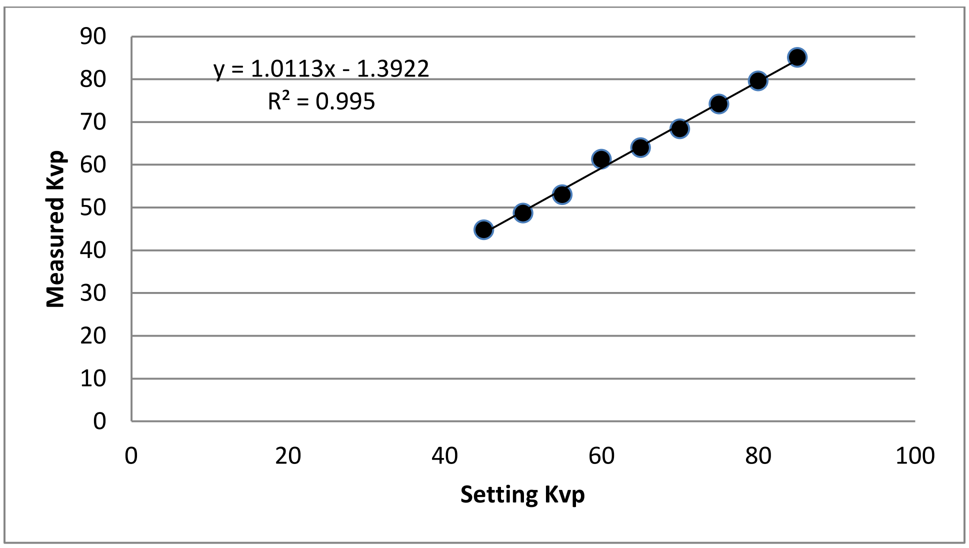


Figure (4-7) show the relationship between setting Kvp and measured Kvp for machine (4).

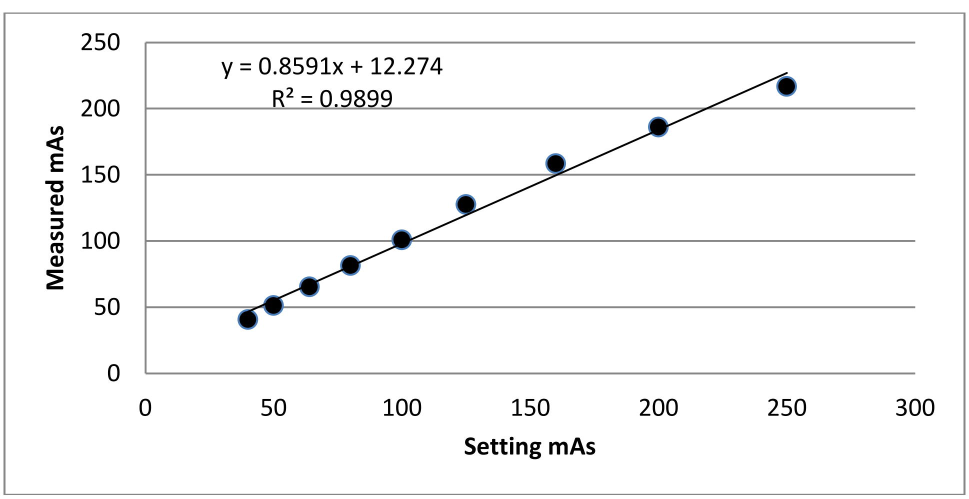


Figure (4-8) show the relationship between setting mAs and measured mAs for machine (4).

Table (4-5) show the setting and measured Kvp and mAs for machine (5).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	85.9	100	101.7
80	81	50	50.5
75	75.2	160	162
70	71.6	200	184.7
65	67.1	250	204.1
60	60.2	80	81.5
55	57.6	360	233.9
50	50.8	64	65.3
45	45.2	40	43.4

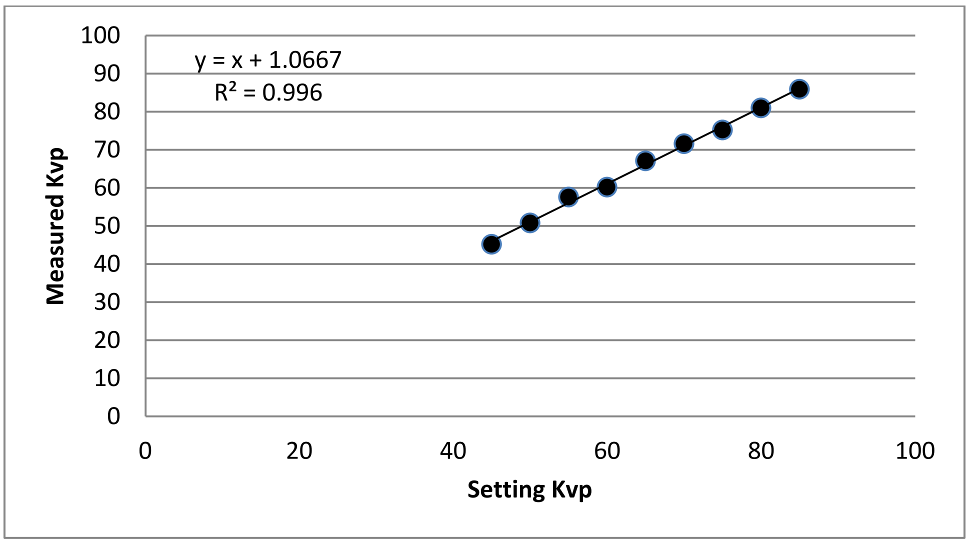


Figure (4-9) show the relationship between setting Kvp and measured Kvp for machine (5).

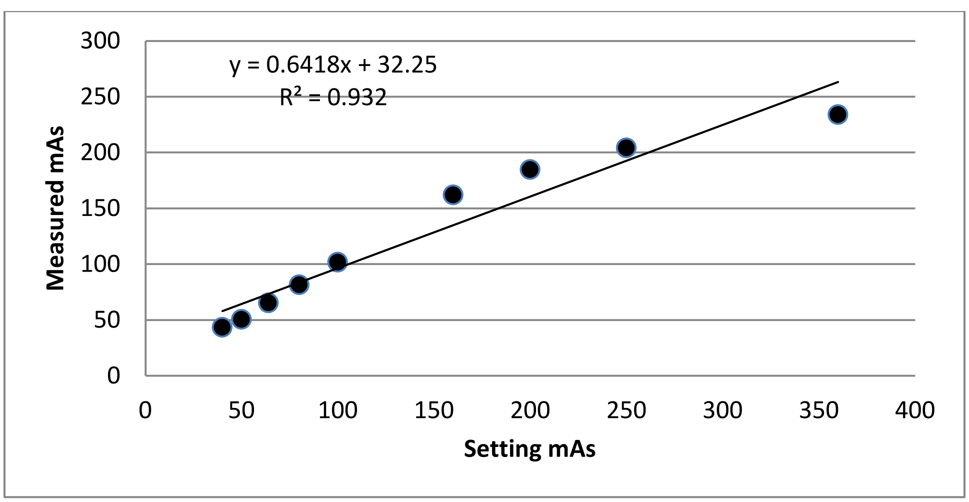


Figure (4-10) show relationship between setting mAs and measured mAs for machine (5).

Table (4-6) show the setting and measured Kvp and mAs for machine (6).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	84.1	40	40.8
80	79.9	50	51.7
75	76.3	80	80.4
70	69	100	102
65	63.7	160	166.8
60	59.3	125	130.9
55	55.3	320	216.5
50	50	200	189.1
45	45.6	64	64.4

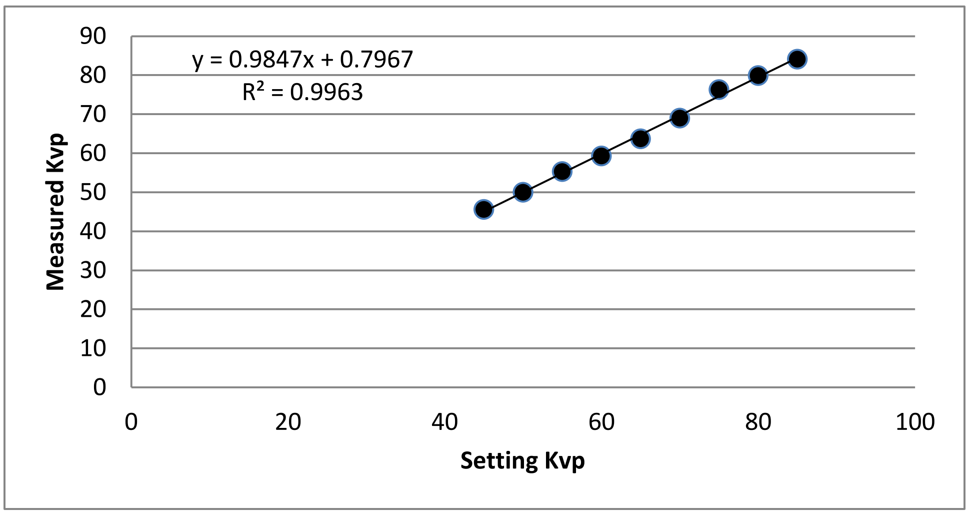


Figure (4-11) show the relationship between setting Kvp and measured Kvp for machine (6).

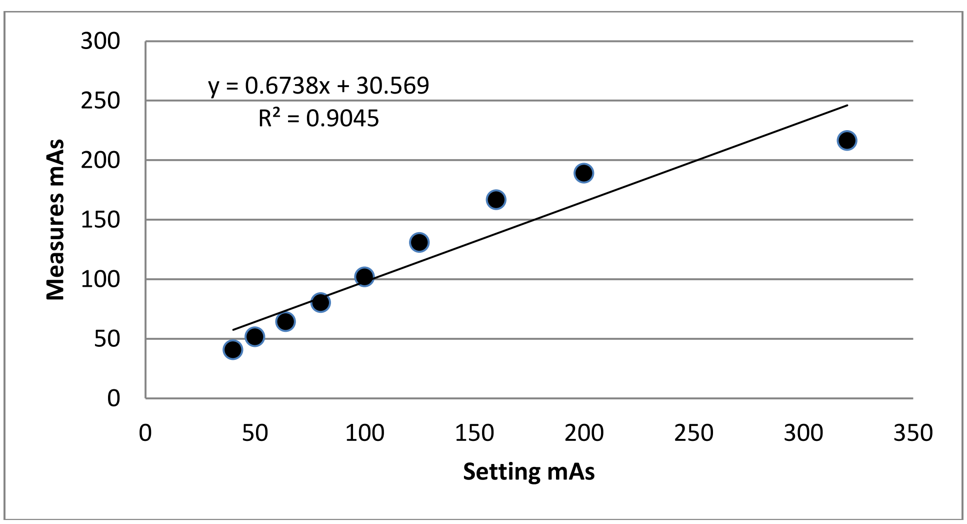


Figure (4-12) show relationship between setting mAs and measured mAs for machine (6).

Table (4-7) show the setting and measured Kvp and mAs for machine (7).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	74	360	278.5
80	69.9	320	219
75	66.3	400	308.1
70	60.8	160	159.1
65	62	200	191.7
60	58.7	100	100.4
55	54.1	80	79.2
50	49.3	50	51.6
45	41.6	64	63

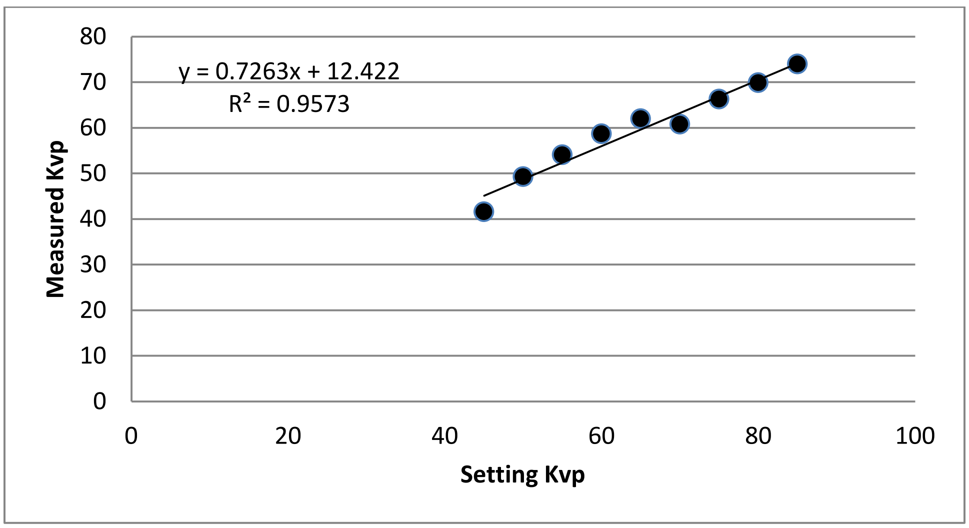


Figure (4-13) show the relationship between setting Kvp and measured Kvp for machine (7).

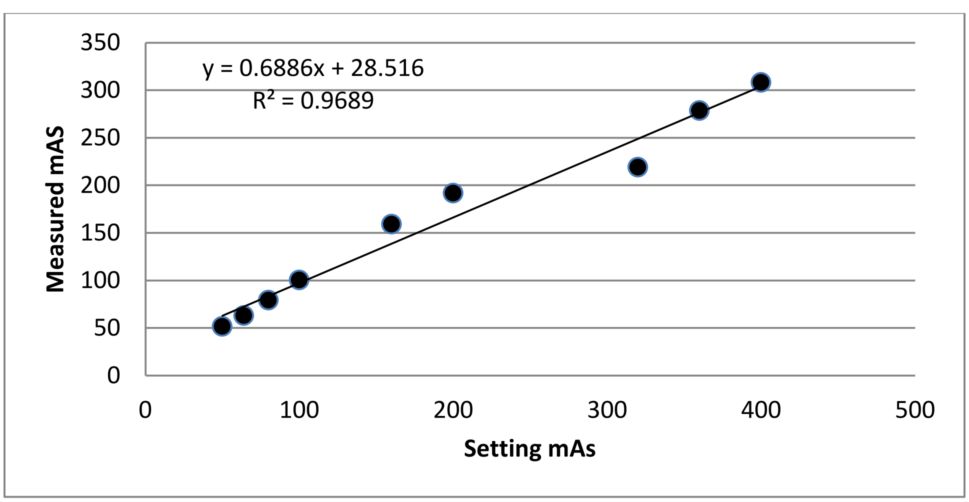


Figure (4-14) show relationship between setting mAs and measured mAs for machine (7).

Table (4-8) show the setting and measured Kvp and mAs for machine (8).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	86.2	160	158
80	80.9	100	99.8
75	75.3	64	64
70	70.8	40	40.3
65	65.7	50	51.1
60	60	80	80.8
55	54.1	250	247.2
50	51	200	198.6
45	45.3	125	124.1

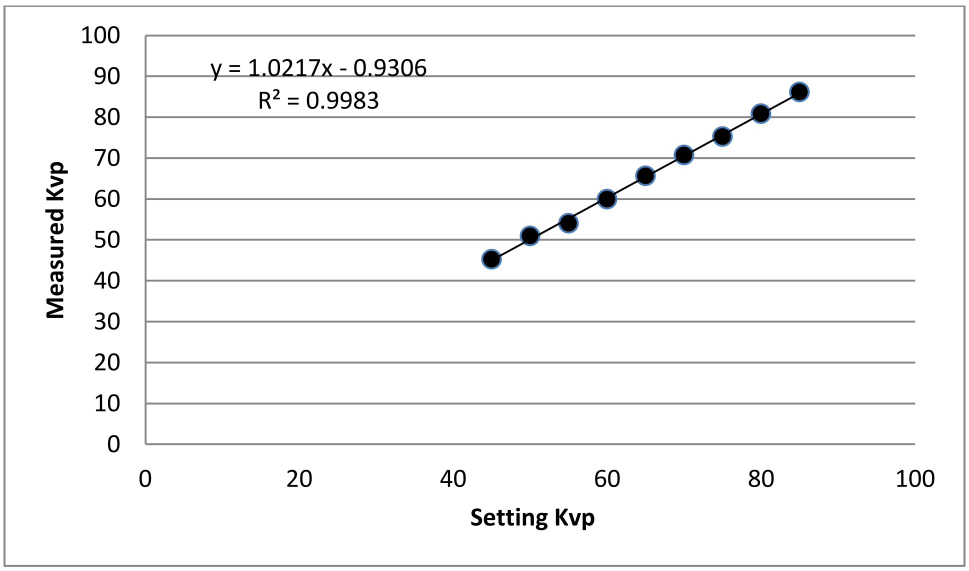


Figure (4-15) show the relationship between setting Kvp and measured Kvp for machine (8).

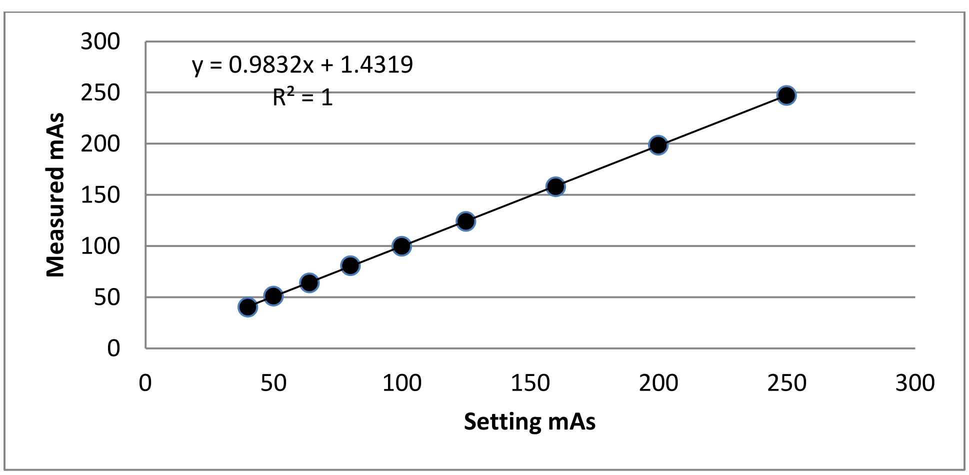


Figure (4-16) show relationship between setting mAs and measured mAs for machine (8).

Table (4-9) show the setting and measured Kvp and mAs for machine (9).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	86.2	100	106
80	80.9	400	321.9
75	77.6	80	84.3
70	73	160	145.2
65	65.7	360	289.6
60	61.9	40	43.7
55	56.6	64	69.1
50	54	320	216.8
45	43.5	200	166.8

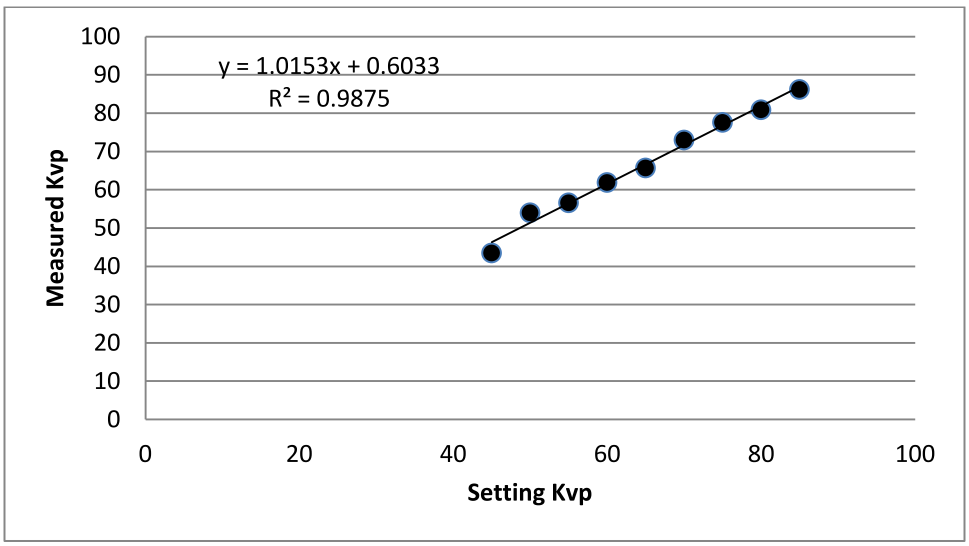


Figure (4-17) show the relationship between setting Kvp and measured Kvp for machine (9).

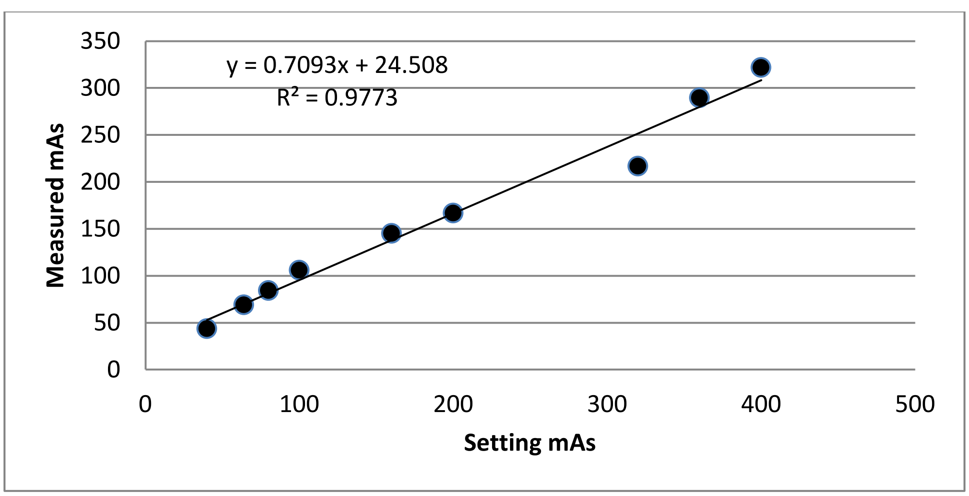


Figure (4-18) show relationship between setting mAs and measured mAs for machine (9).

Table (4-10) show the setting and measured Kvp and mAs for machine (10).

kilo voltage		Milliampire second	
Setting	Measured	Setting	Measured
85	85	40	41.1
80	79.8	50	50.3
75	75.5	64	64.6
70	71	80	81.2
65	65.4	100	100.7
60	59.5	200	175
55	53.9	125	122.9
50	50	160	159.7
45	45.3	250	238.5

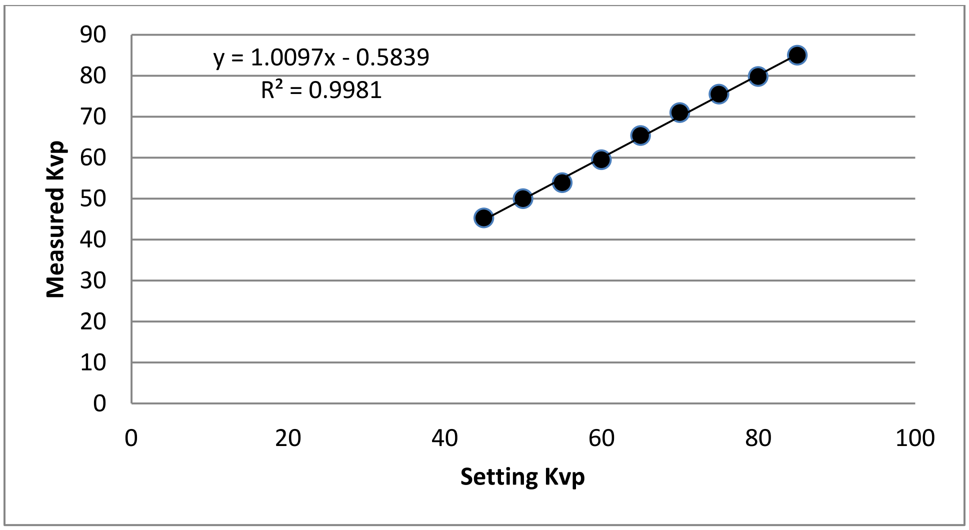


Figure (4-19) show the relationship between setting Kvp and measured Kvp for machine (10).

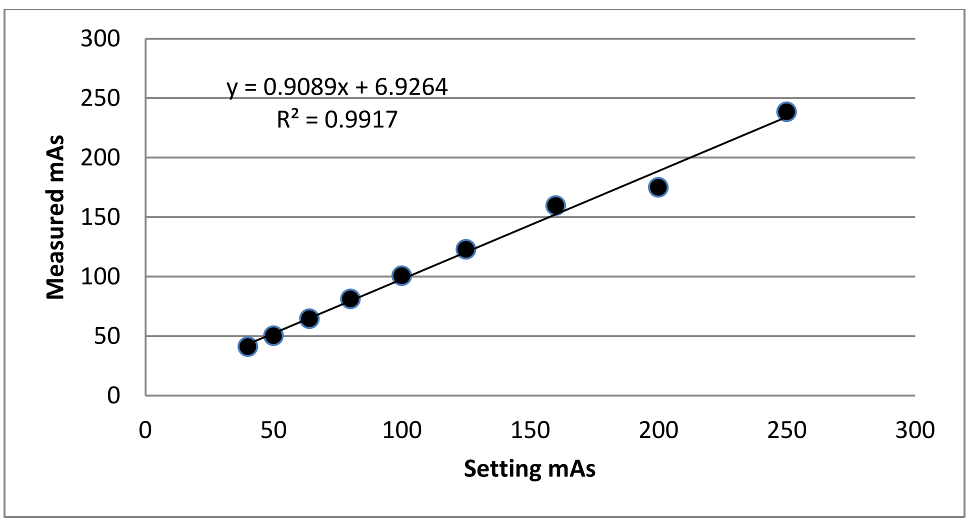


Figure (4-20) show relationship between setting mAs and measured mAs for machine (10).

Chapter Five

Discussion, Conclusion and Recommendation

5.1 Discussions:

The absence of exposure factors accuracy play a role in declination of the medical services standard and lead to the lack of manual operations, anatomical and the fact that the exposure chart was improbably used in the radiology departments and referring to image quality the poor quality image mainly due to bad positioning, bad selection of exposure factors. This study aimed to determine the Accuracy of Exposure Factors in Conventional X-ray Machines by using multifunction meter (Kv and mAs) the main result show that there was small variation between the stated (kv and mAs) and (kv and mAs) measured by the kv meter. after the final result was analysed by (SPSS) , the result showed that 50% of x-rays machines in the acceptable range and 50% of x-rays machines in the unacceptable range, when comparison between applied and measured kilovoltage. and 90% of x-rays machines in the acceptable range and 10% of x-rays machines in the unacceptable range when comparison between sitting and measured mAs.

5.2 Conclusion:

The misunderstanding of the staff to their roles in implementing quality program, in addition to the absence of essential advantage testing tools, this made most x-ray department units in Khartoum state not calibrated which result in poor image quality. By implementing of kv and time accuracy program many benefits can be reached. Saving of money by reducing material usage, save time, and reduce the radiation dose to both patient and the staff. Finally it is clear that applying of QC program concerning kV and time accuracy is very important to the production of image quality.

5.3 Recommendation:

Establishment of QC teams this to include the QC technologist, radiation protection officer, and medical physicist for controlling the quality.

Proper training courses should be established to improve staff skills regarding quality control.

Essential test tools must be available in all departments.

Establishment of staff regular meeting to discuss image quality.

Controlling the exposure factor by introduce anatomical setting and exposure chart.

5.4 References:

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5.5 Appendix:

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (1).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
.06667	.91652	.30551	-.63783-	.77116	.218	8	.833

The table show Paired Samples Test for setting mAs and measured mAs for machine (1).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
5.86556E1	71.95778	23.98593	3.34391	113.96721	2.445	8	.040

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (2).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
6.24444	1.73861	.57954	4.90803	7.58086	10.775	8	.000

The table show Paired Samples Test for setting mAs and measured mAs for machine (2).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
4.51111	18.13005	6.04335	-9.42488-	18.44710	.746	8	.477

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (3).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
2.37778	2.25432	.75144	.64496	4.11060	3.164	8	.013

The table show Paired Samples Test for setting mAs and measured mAs for machine (3).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
2.40000	10.13509	3.37836	-5.39052-	10.19052	.710	8	.498

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (4).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
.65556	.99513	.33171	-.10937-	1.42048	1.976	8	.084

The table show Paired Samples Test for setting mAs and measured mAs for machine (4).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
4.46667	11.89590	3.96530	-4.67733-	13.61067	1.126	8	.293

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (5).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
1.06667 E0	.87034	.29011	-1.73567-	-.39766-	-3.677-	8	.006

The table show Paired Samples Test for setting mAs and measured mAs for machine (5).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
1.96556 E1	42.99372	14.33124	-13.39235-	52.70346	1.372	8	.207

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (6).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
.20000	.85000	.28333	-.45337-	.85337	.706	8	.500

The table show Paired Samples Test for setting mAs and measured mAs for machine (6).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
1.07111 E1	35.15574	11.71858	-16.31198-	37.73421	.914	8	.387

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (7).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
5.36667	4.29651	1.43217	2.06408	8.66926	3.747	8	.006

The table show Paired Samples Test for setting mAs and measured mAs for machine (7).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
3.14889 E1	45.33069	15.11023	-3.35536-	66.33314	2.084	8	.071

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (8).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
-.47778-	.64377	.21459	-.97263-	.01707	-2.226-	8	.057

The table show Paired Samples Test for setting mAs and measured mAs for machine (8).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
.56667	1.30863	.43621	-.43923-	1.57257	1.299	8	.230

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (9).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
- 1.60000 E0	1.57639	.52546	-2.81172-	-.38828-	-3.045-	8	.016

The table show Paired Samples Test for setting mAs and measured mAs for machine (9).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
3.11778 E1	42.38661	14.12887	-1.40345-	63.75901	2.207	8	.058

The table show Paired Samples Test for setting Kvp and measured Kvp for machine (10).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
-.04444-	.61056	.20352	-.51376-	.42487	-.218-	8	.833

The table show Paired Samples Test for setting mAs and measured mAs for machine (10).

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
3.88889	8.86869	2.95623	-2.92819-	10.70597	1.315	8	.225