Chapter One

1.1. Introduction:

Quality assurance means the planned and systematic actions that provide adequate confidence that a diagnostic x-ray facility will produce consistently high quality images with minimum exposure of the patients and healing arts personnel. The determination of what constitutes high quality will be made by the facility producing the images. Quality assurance actions include both “quality control” techniques and “quality administration” procedures.(John, 2001)

Quality assurance program is an organized entity designed to provide “quality assurance” for a diagnostic radiology facility. The nature and extent of this program will vary with the size and type of the facility, the type of examinations conducted, and other factors. (John Winston, 2001)

The Quality Assurance (QA) Program is a program designed by management to assure quality of a product or service. Such a program can have wide-ranging aspects, including customer feedback, employee empowerment, and quality control. Quality control involves specific actions designed to keep measurable aspects of the process involved in manufacturing a product or providing a service within specified limits. These actions typically involve measurement of a process variable, checking the measured value against a limit, and performing corrective action if the limit is exceeded. This document suggests such variables, methods for measurement, control limits, and in some cases corrective actions typically applied to control equipment performance in radiological imaging.(John, 2001)

Quality assurance in medical imaging is a rapidly evolving concept and each facility is encouraged to continually pursue ways to improve and expand its program.(John, 2001)

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.(Taha,2010)
Beam alignment is designed to confirm that the X-ray field and light field are the same.

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. Improper beam alignment of x-ray tube increase radiation dose to the patient and reduce image quality , misalignment may result in unnecessary exposure tothe anatomical area in the patient or repeat exposure.

1.3. Objectives:

1.3.1. General objectives:

To determine the Accuracy of x-ray tube beam alignment in Khartoum state.

1.3.2. Specific Objectives:

- Check the accuracy ofof x-ray tube beam alignment.
- Assure the perpendicular X-ray beam incident the patient.

- Explore and analyze the x-ray beam alignment which help in image quality x-ray.

1.4 The layout:

This study composed of five chapters, chapter one is introduction, problem of study and objective, chapter two background and pervious study, chapter three material and methods, chapter four results and chapter five discussion, conclusion and recommendation.

Chapter Two

Background and Literature review

2.1 introduction:

x-rays are produced when highly energetic electrons interact with matter, converting some of their kinetic energy into electromagnetic radiation. A device that produces x-rays in the diagnostic energy range typically contains an electron source, an evacuated path for electron acceleration, a target electrode, and an external power source to provide a high voltage (potential difference) to accelerate the electrons. Specifically, the x-ray tube insert contains the electron source and target within an evacuated glass or metal envelope; the tube housing provides protective radiation shielding and cools the x-ray tube insert; the x-ray generator supplies the voltage to accelerate the electrons; x-ray beam filters at the tube port shape the x-ray energy spectrum; and collimators define the size and shape of the x-ray field incident on the patient. The generator also permits control of the x-ray beam characteristics through the selection of voltage, current, and exposure time. These components work in concert to create a beam of x-ray photons of welldefined intensity, penetrability, and spatial distribution.(Jerrold et al, 2012)

2.2X-ray Tubes:

The x-ray tube provides an environment for the production of bremsstrahlung and characteristic x-rays.

Major tube components are the cathode, anode, rotor/stator, glass or metal envelope, tube port, cable sockets, and tube housingsupplies the power and permits selection of tube voltage, tube current, and exposure time. Depending upon the type of imaging examination and the characteristics of the anatomy being imaged, the x-ray tube voltage is set to values from 40 to 150 kV for diagnostic imaging, and 25 to 40 kV for mammography. The x-ray tube current, measured in milliamperes (mA), is proportional to the number of electrons per second flowing from the cathode to the anode, where 1 mA = 6.24 X 1015 electrons/s. For continuous fluoroscopy, the tube current is relatively low, from 1 to 5 mA, and for projection radiography, the tube current is set from 50 to 1,200 mA in conjunction with short exposure times (typically less than 100 ms). (In pulsed fluoroscopy, the tube current is commonly delivered in short pulses instead of being continuous; the average tube current is typically in the range of 10 to 50 mA, while the overall number of electrons delivered through the tube is about the same per image.) The kV, mA, and exposure time are the three major selectable parameters on the x-ray generator control panelthat

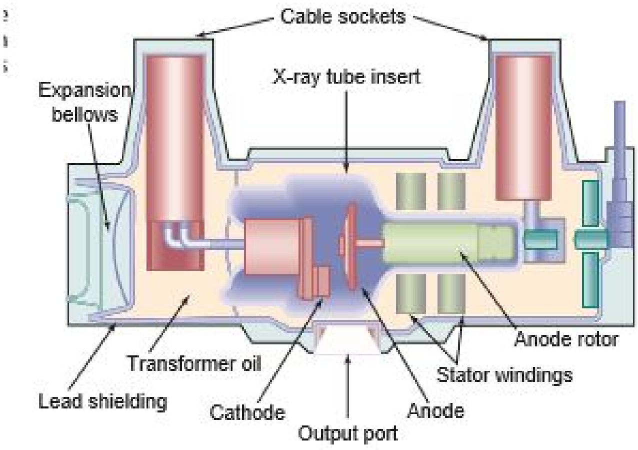

Fig: (2.1) Generation of a characteristic x-ray and housing assembly.

determine the x-ray beam characteristics. Often, the product of the tube current and exposure time are considered as one entity, the mAs (milliampere-second; technically, mAs is a product of two units but, in common usage, it serves as a quantity). (Jerrold et al, 2012)

2.2.1 Cathode:

The cathode is the negative electrode in the x-ray tube, comprised of a filament or filaments and a focusing cup. A filament is made of tungsten wire wound in a helix, and is electrically connected to the filament circuit, which provides a voltage of approximately 10 V and variable current up to 7,000 mA (7 A). Most x-ray tubes for diagnostic imaging have two filaments of different lengths, each positioned in a slot machined into the focusing cup, with one end directly connected to the focusing cup, and the other end electrically insulated from the cup by a ceramic insert. Only one filament is energized for an imaging examination. On many x-ray systems, the small or the large filament can be manually selected, or automatically selected by the x-ray generator depending on the technique factors (kV and mAs). When energized, the filament circuit heats the filament through electrical resistance, and the process of thermionic emission releases electrons from the filament surface at a rate determined by the filament current and corresponding filament temperature. Heat generated by resistance to electron flow in the filament raises the temperature to a point where electrons can leave the surface. However, electrons flow from the cathode to the anode only when the tube voltage is applied between these electrodes. The numbers of electrons that are available are adjusted by the filament current and filament temperature, where small changes in the filament current can produce relatively large changes in tube current. Outputof the x-ray tube is emission-limited, meaning that the filament current determines the x-ray tube current; at any kV, the x-ray flux is proportional to the tube current. Higher tube voltages also produce slightly higher tube current for the same filament current. A filament current of 5 A at a tube voltage of 80 kV produces a tube current of about 800 mA, whereas the same filament current at 120 kV produces a tube current of about 1,100 mA. In most x-ray tubes, the focusing cup is maintained at the same potential difference as the filament relative to the anode, and at the edge of the slot, an electric field exists that repels and shapes the cloud of emitted electrons from the filament surface. As a large voltage is applied between the cathode and anode in the correct polarity, electrons are accelerated into a tight distribution and travel to the anode, striking a small area called the focal spot . The focal spot dimensions are determined by the length of the filament in one direction and the width of electron distribution in the perpendicular direction. A biased x-ray tube has a focusing cup totally insulated from the filament wires so that its voltage is independent of the filament. Because high voltages are appliedto the cathode, electrical insulation of the focusing cup and the bias supply voltage is necessary, and can add significant expense to the x-ray system. A voltage of about 100 V negative is applied with respect to the filament voltage to further reduce the spread of electrons and produce a smaller focal spot width. Even greater negative applied voltage (about −4,000 V) to the focusing cup actually stops the flow of electrons, , which cause motion artifacts and produce lower average x-ray energies and unnecessary patient dose. Ideally, a focal spot would be a point, eliminating geometric blurring. However, such a focal spot is not possible and, if it were, would permit only a tiny tube current. In practice, a finite focal spot area is used with an area large enough to permit a sufficiently large tube current and short exposure time. For magnification studies, a small focal spot is necessary to limit geometric blurring and achieve adequate spatial resolution.(Jerroldet al, 2012)

2.2.2 **Anode:**

The anode is a metal target electrode that is maintained at a large positive potential difference relative to the cathode. Electrons striking the anode deposit most of their energy as heat, with only a small fraction emitted as x-rays. Consequently, the production of x-rays, in quantities necessary for acceptable image quality, generates a large amount of heat in the anode. To avoid heat damage to the x-ray tube, the rate of x-ray production (proportional to the tube current) and, at large tube currents,

Unbiased the duration of x-ray production, must be limited. Tungsten (W, Z = 74) is the most widely used anode material because of its high melting point and high atomic number. A tungsten anode can handle substantial heat deposition without cracking or pitting of its surface. An alloy of 10% rhenium and 90% tungsten provides added resistance to surface damage. Tungsten provides greater bremsstrahlung production than elements with lower atomic numbers . Molybdenum (Mo, Z = 42) and rhodium (Rh, Z = 45) are used as anode materials in mammographic x-ray tubes.(Jerrold et al, 2012)

2.3Production of x-rays:

2.3.1 Bremsstrahlung Spectrum:

x-rays are created from the conversion of kinetic energy of electrons into electromagnetic radiation when they are decelerated by interaction with a target material. A simplified diagram of an x-ray tube. For diagnostic radiology, a large electric potential difference (the SI unit of potential difference is the volt, V) of 20,000 to 150,000 V (20 to 150 kV) is applied between two electrodes (the cathode and the anode) in the vacuum. The cathode is the source of electrons, and the anode, with a positive potential with respect to the cathode, is the target of electrons. As electrons from the cathode travel to the anode, they are accelerated by the voltage between the electrodes and attain kinetic energies equal to the product of the electrical charge and potential difference . A common unit of energy is the electron volt (eV), equal to the energy attained by an electron accelerated across a potential difference of 1 V. Thus, the kinetic energy of an electron accelerated by a potential difference of 50 kV is 50 keV.

One eV is a very small amount of energy. On impact with the target, the kinetic energy of the electrons is converted to other forms of energy. The vast majority of interactions are collisional, whereby energy exchanges with electrons in the target give rise to heat. A small fraction of the accelerated electrons comes within the proximity of an atomic nucleus and is influenced by its positive electric field. electrical forces attract and decelerate an electron and change its direction, causing a loss of kinetic energy, which is emitted as an x-ray photon of equal energy(i.e., bremsstrahlung radiation).(Jerrold et al, 2012)

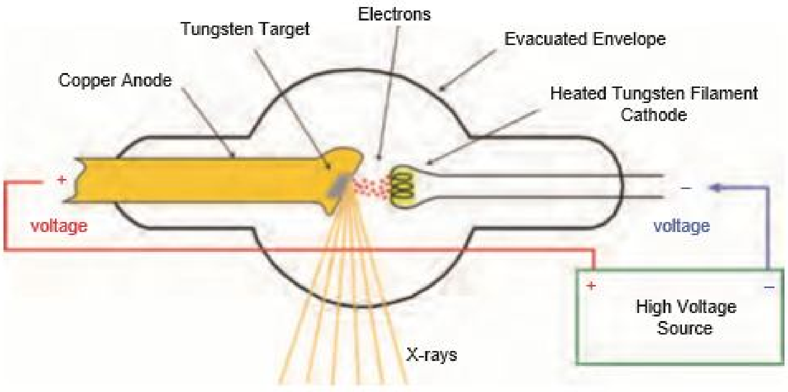

Fig: (2.2) Minimum requirements for x-ray production include a source and target of electrons, an evacuated envelope, and connection of the electrodes to a high-voltage source.(Jerroldet al, 2012)

The amount of energy lost by the electron and thus the energy of the resulting x-ray are determined by the distance between the incident electron and the target nucleus, since the Coulombic force is proportional to the inverse of the square of the distance. At relatively large distances from the nucleus, the Coulombic attraction is weak; these encounters produce low x-ray energies . At closer interaction distances, the force acting on

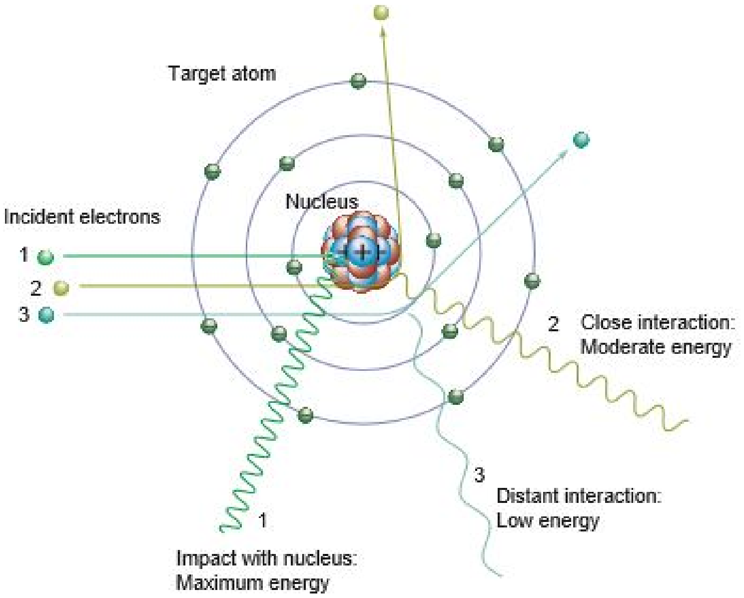

Fig: (2.3) Bremsstrahlung radiation arises from energetic electron interactions with an atomic nucleus of the target material. In a “close” approach, the positive nucleus attracts the negative electron, causing deceleration and redirection, resulting in a loss of kinetic energy that is converted to an x-ray. The x-ray energy depends on the interaction distance between the electron and the nucleus; it decreases as the distance increases.(Jerroldet al, 2012)

the electron increases, causing a greater deceleration; these encounters produce higher x-ray energies. A nearly direct impact of an electron with the target nucleus results in loss of nearly all of the electron’s kinetic energy. In this rare situation, the highest x-ray energies are produced. The probability of electron interactions that result in production of x-ray energy E is dependent on the radial interaction distance, r, from the nucleus, which defines a circumference, 2pr. With increasing distance from the nucleus, the circumference increases, and therefore the probability of interaction increases, but the x-ray energy decreases. Conversely, as the interaction distance, r, decreases, the x-ray energy increases because of greater electron deceleration, but the probability of interaction decreases. For the closest electron-atomic nuclei interactions, the highest x-ray energies are produced. However, the probability of such an interaction is very small, and the number of x-rays produced is correspondingly small. The number of x-rays produced decreases linearly with energy up to the maximal x-ray energy, which is equal to the energy of the incident electrons. A bremsstrahlung spectrum is the probability distribution of x-ray photons as a function of photon energy (keV). The unfiltered bremsstrahlung spectrum, with the highest x-ray energy determined by the peak voltage (kV) applied across the x-ray tube. A typical filtered bremsstrahlung spectrum has no x-rays below about 10 keV; the numbers increase to a maximum at about one third to one half the maximal x-ray energy and then decrease to zero as the x-ray energy increases to the maximal x-ray energy. Filtration in this context refers to the removal of x-rays by attenuation in materials that are inherent in the x-ray tube, as well as by materials that are purposefully placed in the beam, such as thin aluminum and copper sheets, to remove lower energy x-rays and adjust the spectrum for optimal low-dose imaging Major factors that affect x-ray production efficiency include the atomic number of the target material and the kinetic energy of the incident electrons. The approximate ratio of radiative energy loss caused by bremsstrahlung production to collisional (excitation and ionization) energy loss within the diagnostic x-ray energy range (potential difference of 20 to 150 kV) is expressed as follows:

$$\frac{\text{Radiative energy loss}}{\text{Collisional energy loss}} \cong \frac{E_k Z}{820{,}000}$$

(Jerrold et al, 2012)

where EK is the kinetic energy of the incident electrons in keV, and Z is the atomic number of the target electrode material. The most common target material is tungsten (W, Z = 74); in mammography, molybdenum

(Mo, Z = 42) and rhodium (Rh, Z = 45) are also used. For 100-keV electrons impinging on tungsten, the approximate ratio of radiative to collisional losses is (100 x 74)/820,000=0.009 = 0.9%; therefore, more than 99% of the incident electron energy on the target electrode is converted to heat and nonuseful low-energy electromagnetic radiation. At much higher electron energies produced by radiation therapy systems (millions of electron volts), the efficiency of x-ray production is dramatically increased. (Jerrold et al, 2012)

2.3.2 Characteristic x-ray Spectrum:

In addition to the continuous bremsstrahlung x-ray spectrum, discrete x-ray energy peaks called “characteristic radiation” can be present, depending on the elemental composition of the target electrode and the applied x-ray tube voltage. Electrons in an atom are distributed in shells, each of which has an electron binding energy. The innermost shell is designated the K shell and has the highest electron binding energy, followed by the L, M, and N shells, with progressively less binding energy. When the energy of an incident electron, determined by the voltage applied to the x-ray tube, exceeds the binding energy of an electron shell in a target atom, a collisional interaction can eject an electron from its shell, creating a vacancy. An outer shell electron with less binding energy immediately transitions to fill the vacancy, and a characteristic x-ray is emitted with an energy equal to the difference in the electron binding energies of the two shells . For tungsten, an L-shell (binding energy = 10.2 keV) electron transition to fill a K-shell (binding energy = 69.5 keV) vacancy produces a characteristic x-ray with a discrete energy of

$$\mathbf{E_{bk} - E_{bl}} = 69.5 \text{ kev} - 10.2 \text{ kev} = 59.3 \text{ kev}$$

Electron transitions occur from adjacent and nonadjacent electron shells in the atom, giving rise to several discrete characteristic energy peaks superimposed on the

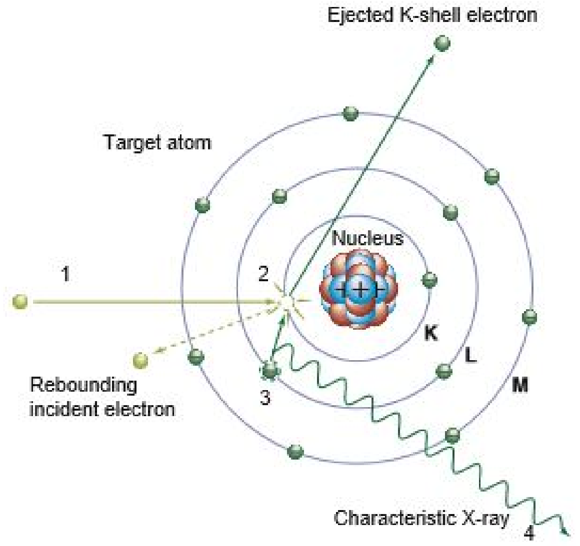

Fig: (2.4)Generation of a characteristic x-ray in a target atom occurs in the following sequence: (1) The incident electron interacts with the K-shell electron via a repulsive electrical force. (2) The K-shell electron is removed (only if the energy of the incident electron is greater than the K-shell binding energy), leaving a vacancy in the K-shell. (3) An electron from the adjacent L-shell (or possibly a different shell) fills the vacancy. (4) A Ka characteristic x-ray photon is emitted with energy equal to the difference between the binding energies of the two shells. In this case, a 59.3-keV photon is emitted .(Jerrold et al, 2012)

bremsstrahlung spectrum. Characteristic x-rays are designated by the shell in which the electron vacancy is filled, and a subscript of a or b indicates whether the electron transition is from an adjacent shell (a) or nonadjacent shell (b). For example, Ka refers to an electron transition from the L to the K shell, and Kb refers to an electron transition from the M, N, or O shell to the K shell. A Kb x-ray is more energetic than a Ka x-ray. Characteristic x-rays other than those generated by K-shell transitions are too low in energy for any useful contributions to the image formation process and are undesirable for diagnostic imaging. Characteristic K X-rays are produced only when the electrons impinging on the target exceed the binding energy of a K-shell electron. X-ray tube voltages must therefore be greater than 69.5 kV for W targets, 20 kV for Mo targets, and 23 kV for Rh targets to produce K characteristic x-rays. In terms of intensity, as the x-ray tube voltage increases, so does the ratio of characteristic to bremsstrahlung x-rays. For example, at 80 kV, approximately 5% of the total x-ray output intensity for a tungsten target is composed of characteristic radiation, which increases to about 10% at 100 kV. In mammography, characteristic x-rays from Mo and Rh target x-ray tubes are particularly useful in optimizing image contrast and radiation dose.(Jerrold et al, 2012)

2.4. Interactions of X-ray with matter:

When traversing matter, photons will penetrate without interaction, scatter, or be absorbed. There are four major types of interactions of x-ray and gamma-ray photons with matter, the first three of which play a role in diagnostic radiology and nuclear medicine: (a) Rayleigh scattering, (b) Compton scattering, (c) photoelectric absorption, and (d) pair production.

2.4.1 **Rayleigh Scattering:**

In Rayleigh scattering, the incident photon interacts with and excites the total atom. This interaction occurs mainly with very low energy x-rays, such as those used in mammography (15 to 30 keV). During the Rayleigh scattering event, the electric field of the incident photon’s electromagnetic wave expends energy, causing all of the electrons in the scattering atom to oscillate in phase. The atom’s electron cloud immediately radiates this energy, emitting a photon of the same

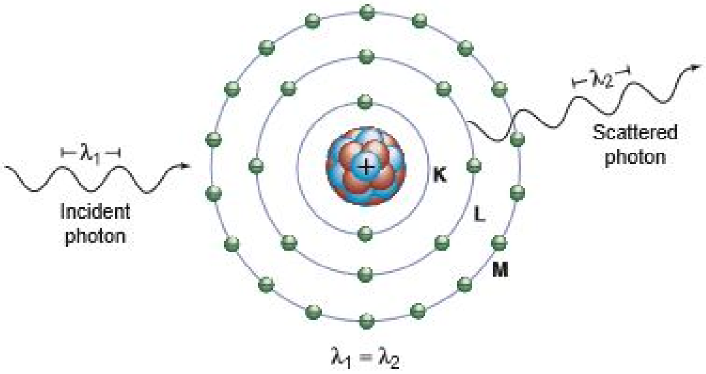

Fig: (2.5) Rayleigh scattering. The diagram shows that the incident photon l1 interacts with an atom and the scattered photon l2 is being emitted with the same wavelength and energy. Rayleigh scattered photons are typically emitted in the forward direction fairly close to the trajectory of the incident photon. K, L, and M are electron shells.(Jerrold et al, 2012)

Energy but in a slightly different direction.In this interaction, electrons are not ejected, and thus, ionization does not occur. In general, the average scattering angle decreases as the x-ray energy increases. In medical imaging, detection of the scattered x-ray will have a deleterious effect on image quality. However, this type of interaction has a low probability of occurrence in the diagnostic energy range. In soft tissue, Rayleigh scattering accounts for less than 5% of x-ray interactions above 70 keV and at most only accounts for about 10% of interactions at 30 keV. Rayleigh interactions are also referred to as “coherent” or “classical” scattering(Jerrold et al, 2012).

2.4.2 The Photoelectric Effect:

In the photoelectric effect, all of the incident photon energy is transferred to an electron, which is ejected from the atom. The kinetic energy of the ejected photoelectron (E_{pe}) is equal to the incident photon energy (E_o) minus the binding energy of the orbital electron

$$E_{pe} = E_o - E_b$$

In order for photoelectric absorption to occur, the incident photon energy must be greater than or equal to the binding energy of the electron that is ejected. The ejected electron is most likely one whose binding energy is closest to, but less than, the incident photon energy. For example, for photons whose energies exceed the K-shell binding energy, photoelectric interactions with K-shell electrons are most probable. Following a photoelectric interaction, the atom is ionized, with an innershell electron vacancy. This vacancy will be filled by an electron from a shell with a lower binding energy. This creates another vacancy, which, in turn, is filled by an electron from an even lower binding energy shell. Thus, an electron cascade from outer to inner shells occurs. The difference in binding energy is released as either characteristic x-rays or Auger electrons. The probability of characteristic x-ray emission decreases as the atomic number of the absorber decreases, and thus, characteristic x-ray emission does not occur frequently for diagnostic energy photon interactions in soft tissue. The photoelectric effect can and does occur with valence shell electrons such as when light

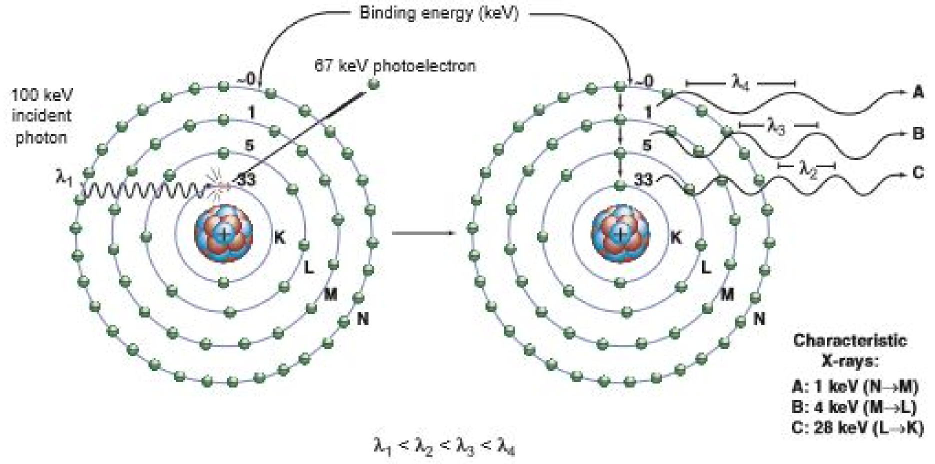

Fig: (2.7) show photoelectric absorption.(Jerrold et al, 2012)

photons strike the high Z materials that comprise the photocathode (e.g., cesium, rubidium and antimony) of a photomultiplier tube. These materials are specially selected to provide weakly bound electrons (i.e.,electrons with a low work function), so when illuminated the photocathode readily releases electrons. In this case, no inner shell electron cascade occurs and thus no characteristic x-rays are produced.
(Jerroldet al, 2012)

2.4.3Compton Scattering:

Compton scattering (also called inelastic or nonclassical scattering) is the predominant interaction of x-ray and gamma-ray photons in the diagnostic energy range with soft tissue. In fact, Compton scattering not only predominates in the diagnostic energy range above 26 keV in soft tissue but also continues to predominate well beyond diagnostic energies to approximately 30 MeV. This interaction is most likely to occur between photons and outer (“valence”)-shell electrons . The electron is ejected from the atom, and the scattered photon is emitted with some reduction in energy relative to the incident photon. As with all types of interactions, both energy and momentum must be conserved. Thus, the energy of the incident photon (E_0) is equal to the sum of the energy of the scattered photon (E_{sc}) and the kinetic energy of the ejected electron (E_e). The binding energy of the electron that was ejected is comparatively small and can be ignored.

$$\mathbf{E_o = E_{sc} + E_{e-}}$$

Compton scattering results in the ionization of the atom and a division of the incident photon’s energy between the scattered photon and the ejected electron. The ejected electron will lose its kinetic energy via excitation and ionization of atoms in the surrounding material. The Compton scattered photon may traverse the medium without interaction or may undergo subsequent interactions such as Compton scattering. The energy of the scattered photon can be calculated from the energy of the incident photon and the angle (with respect to the incident trajectory) of the scattered photon:

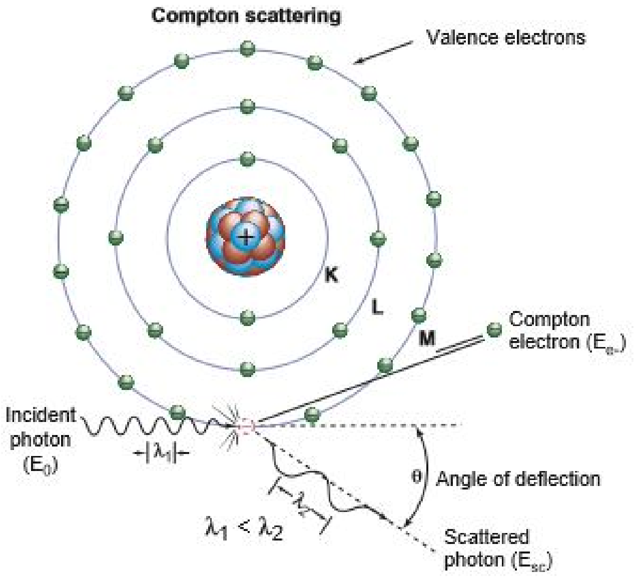

Fig:(2.6) Compton scattering. The diagram shows the incident photon with energy E0, interacting with a valence-shell electron that results in the ejection of the Compton electron (Ee) and the simultaneous emission of a Compton scattered photon Esc emerging at an angle relative to the trajectory of the incident photon. K, L, and M are electron shells (Jerrold et al, 2012)

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When Compton scattering occurs at the lower x-ray energies used in diagnostic imaging (15 to 150 keV), the majority of the incident photon energy is transferred to the scattered photon. For example, following the Compton interaction of an 80-keV photon, the minimum energy of the scattered photon is 61 keV. Thus, even with maximal energy loss, the scattered photons have relatively high energies and tissue penetrability. In x-ray transmission imaging and nuclear emission imaging, the detection of scattered photons by the image receptors results in a degradation of image contrast and an increase in random noise. The laws of conservation of energy and momentum place limits on both scattering angle and energy transfer. For example, the maximal energy transfer to the Compton electron (and thus, the maximum reduction in incident photon energy) occurs with a 180-degree photon scatter (backscatter). In fact, the maximal energy of the scattered photon is limited to 511 keV at 90 degrees scattering and to 255 keV for a 180-degree scattering event. These limits on scattered photon energy hold even for extremely high-energy photons (e.g., therapeutic energy range). The scattering angle of the ejected electron cannot exceed 90 degrees, whereas that of the scattered photon can be any value including a 180-degree backscatter. In contrast to the scattered photon, the energy of the ejected electron is usually absorbed near the scattering site. The incident photon energy must be substantially greater than the electron's binding energy before a Compton interaction is likely to take place. Thus, the relative probability of a Compton interaction increases, compared to Rayleigh scattering or photoelectric absorption, as the incident photon energy increases. The probability of Compton interaction also depends on the electron density (number of electrons/g 3 density). With the exception of hydrogen, the total number of electrons/g is fairly constant in tissue; thus, the probability of Compton scattering per unit mass is nearly independent of Z, and the probability of Compton scattering per unit volume is approximately proportional to the density of the material. Compared to other elements, the absence of neutrons in the hydrogen atom results in an approximate doubling of electron density. Thus, hydrogenous materials have a higher probability of Compton scattering than anhydrogenous material of equal mass.(Jerrold et al, 2012)

2.4.4 Pair Production:

Pair production can only occur when the energies of x-rays and gamma rays exceed 1.02 MeV. In pair production, an x-ray or gamma ray interacts with the electric field of the nucleus of an atom. The photon's energy is transformed into an electron- positron pair. The rest mass energy equivalent of each electron is 0.511 MeV, and this is why the energy threshold for this reaction is 1.02 MeV. Photon energy in excess of this threshold is imparted to the electron (also referred to as a negatron or beta minus particle) and positron as kinetic energy. The electron and positron lose their kinetic energy via excitation and ionization. As discussed previously, when the positron comes to rest, it interacts with a negatively charged electron, resulting in the formation of two oppositely directed 0.511-MeV annihilation photons . Pair production does not occur in diagnostic x-ray imaging because the threshold photon energy is well beyond even the highest energies used in medical imaging. In fact, pair production does not become significant until the photon energies greatly exceed the 1.02-MeV energy threshold.(Jerroldet al, 2012)

2.5. The Quality Control Program:

2.5.1.Equipment Selection:

Quality begins with proper equipment selection. The diagnostic medical physicist, having been educated in the administrative, technical, and clinical aspects of equipment performance, possesses a unique vantage point from which to assess appropriateness of imaging equipment. Equipment must be appropriate in terms of its ability to deliver the quality necessary for a particular imaging task at a cost to both patient and hospital (or clinic) that is reasonable in terms of dose, dollars, and downtime. The medical physicist must be an integral component of the equipment selection process. Prior to the request for a quotation on any imaging device, the medical physicist should compile a set of performance specifications upon which such a quote should be based. These bid specifications will form the basis for acceptance tests to be performed upon installation. As such, they will necessarily be detailed and should be as specific as possible in terms of the tests to be performed and the results expected. The performance levels stated in these specifications should reflect the anticipated needs for successful utilization of the procedure room as envisioned by the radiologists and technologists. Specifications should include requirements for: Generators,X-ray tube assemblies, Patient support assemblies, Image receptors or video chains, Display systems, Archival systems,Gantry configuration and Peripheral devices.(Shepard et al , 2002)

2.5.2. Acceptance Test:

Once an appropriate system has been selected and installed, it is the diagnostic medical physicist’s responsibility to assure that the equipment functions safely, according to all published claims made by the vendor, and as agreed to in any contract-related documents created during the selection process (including the bid specifications). Documentation of the system performance during the warranty period may become a critical issue and hence must be carefully maintained.(Shepard et al , 2002)

2.6. Quality Control:

Following successful installation and acceptance, equipment must be monitored on an ongoing basis to ensure continued, reliable performance. This ongoing, periodic evaluation procedure is quality control (QC). The purpose of QC testing is to detect changes that may result in a clinically significant degradation in image quality or a significant increase in radiation exposure.(Shepard et al , 2002)

2.6.1. Documentation:

Test results should be recorded in a database for analysis. Performance comparisons should be made routinely to assure constancy in the performance of each device as well as consistency between devices. For instance, in a department with four chest Bucky devices, it is essential that the generator, phototimer, and processor system in all the rooms produce the same radiographic density and contrast for a given phantom. Routine comparisons of results between rooms and processors will assure consistency.(Shepard et al , 2002)

2.6.2. Staffing Considerations:

Routine (daily, weekly, and monthly) QC testing should be performed by a technologist and reviewed periodically by a diagnostic medical physicist. This testing is normally performed with simple QC instruments and phantoms. Tests with quarterly to annual frequencies may be performed either by a diagnostic medical physicist or a well-trained QC technologist working under the supervision of a medical physicist, depending upon the complexity of the test and the competency of the technologist. Responsibility for training of all personnel utilized for quality control and analysis of all results is the responsibility of the diagnostic medical physicist.(Shepard et al , 2002)

2.6.3. QC INSTRUMENTATION:

The choice of instrumentation for performance of QC and acceptance testing depends upon the type of radiological equipment to be evaluated and the intended user. Instrumentation needs should be determined on a case-by-case basis. To assist in the selection of appropriate instrumentation, refer to AAPM Report No. 60.6 the report contains a compilation of instrumentation requirements for use in evaluation of radiographic and fluoroscopic equipment along with recommended performance capabilities that can be used for specifications prior to purchase. The instrumentation is intended for use by or under the direction of qualified diagnostic medical physicists. There are specific recommendations on routine QC instruments as well as more sophisticated instrumentation useful for higher level testing such as may be necessary for acceptance tests.(Shepard et al, 2002)

2.7. Light field/X-ray field alignment (congruence):

The alignment between the light field and the radiation field permits the technologist to position the field to expose only the anatomy of interest. Misalignment may result in unnecessary or repeat exposure. Testing should be performed at least annually on new equipment. The functionality of the field light should be confirmed as well as the adequacy of the field illumination. The Code of Federal Regulations (21 CFR) currently requires that the individual x-ray field and light field borders agree to within ±2% of the SID.(Shepard et al, 2002)

2.7.1. Method of test:

2.7.1.1 Light field /beam alignment test:

This procedure is designed to confirm that the x-ray field and light field are the same.

2.7.1.2Equipment:

8 x 10 image receptor

Collimator test template

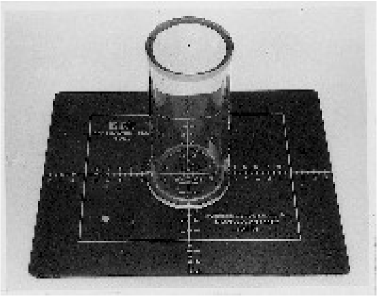


Fig (2.8) Beam alignment test tool

6-inch carpenter's level

Ruler whith centimeter and inch markings

2.7.1.3Procedure:

Place the template on top of the Image receptor on the tabletop.

Center the tube to the image receptor and set the tube a 40-inch SID.

Use the 6-inch carpenter's level to check that the tube and the tabletop are level .

Place the template on top the image receptor .the dot in the corner of the template should correspond to the patients right shoulder. The dot helps to determine the direction of Collimator error later.

Collimate the x-ray beam to the rectangular outline on the template. This area is approximately 7 x 5 inches.

Set and approximate technique of 10mAs at 60kVp for single-phase units and 2.5 mAs at 60kVp for three-phase units. The selected technique depends on the speed of the image receptor system.

Expose the film.

Open the collimator shutters to an 8 x 10 size and expose the film again using a technique of 0.4 mAs at 45 Kv.

Process the film.Measure the image.

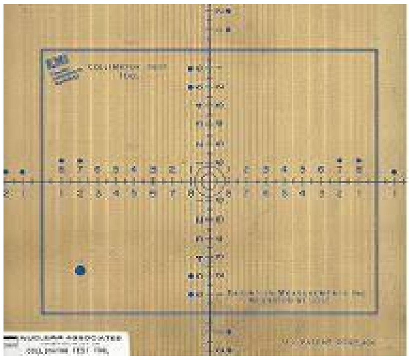


Fig (2.9) Template image.Record the results.(Andrea).

2.7.2 Test Procedure- Routine Test

Position the x-ray source over the tabletop so that the distance from source to tabletop is 40in(l00 cm).

Inspect the collimator.

Place the loaded 8in x 10in cassette on the tabletop. Position the 9 pennies, center the cassette, and adjust

the collimator so that the light field is as shownbelow. Make the exposure to give a medium density (about 1.0

type. ex. 60 kVp, 5 mAs). Develop and inspect the film. Save the film for comparison in future tests.(AAPM REPORT No.4 , 1977)

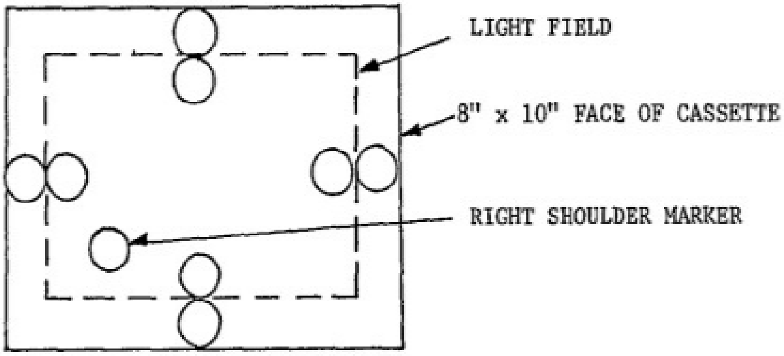


Figure (2.10): showstheArrangementofexperimental set up for exposure. (Siedband, 1977)

2.7.3. Alternate Method

-Place a 10 x 12 inch (24 x 30 cm) loaded cassette in the bucky and set the SID at 40 inches (100 cm).

- If possible, adjust the field size to 6 x 8 inches (15 x 20 cm). The field must be smaller than the film. If your system is not equipped with a variable collimator, attach a beam limiting device (BLD) that provides a field size smaller than the cassette.

- Place the coins as shown in Figure.

- Expose (65 kVp, 4 mAs) and develop the film. If field edges are not well defined, adjust techniques accordingly and repeat this step.

- Measure the distances between the light (where the coins touch) and x-ray fields for all coin locations.

- Add differences for each set of coins along and across the film, and divide each set of differences by the SID (Example: (1.5" along table / 40")(100) = 3.75% and (0.5" across table / 40")(100) =1.25%).

- Percentage differences greater than 2.0% in either direction should be corrected as soon as possible.

- Using the same exposed film, determine the center of the x-ray field.

- In the same manner, determine the center of the film.

- Measure distance between the two centers and calculate the difference as a percentage of the SID. If the percentage difference is greater than 2.0%, corrective action is necessary.

- Measure the dimensions of the x-ray field on the film. If the difference between the indicated and measured field size exceeds 2% of the SID, corrective action is required.

- Complete Steps 1 through 11 with all cassette holders (i.e., check both the wall and table bucky)

- Record results on the Annual QC Checklist

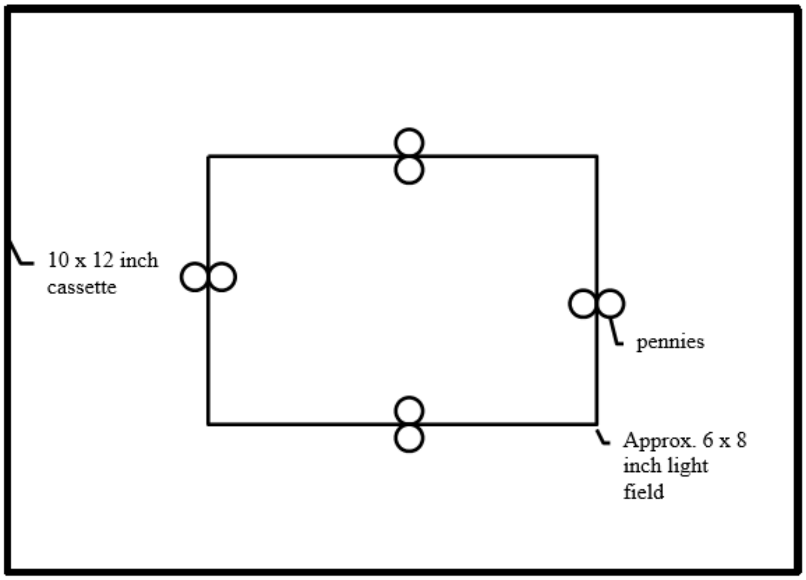


Fig (2.11) shows the arrangement of experimental set for exposure.(John, 2001)

2.8. Previous studies:

Study byAkaagerger et al, (2015), Evaluation of Quality Control of Beam Alignment and Collimator Test Tools on Diagnostic X-Ray Machines inMakurdi, Benue State-Nigeria for two major Hospitals designated A and B was carried out using Beam alignment and Collimator test tools which were based on technical standards for radiological protection and quality control in medical diagnosis. The quality filtration of diagnostic X-ray in use at Hospitals A and B were checked using collimator and beam alignment test were used to measure the degree of misalignment of the target points, Hospital A was shown to have a misalignment of 0.2cm at 60kVp, 10mAs, 100cm FFD using a film size of 10x8cm2 while Hospital B had a misalignment of 0.6cm at 25mAs, 81cm FFD using a film size of 10x8cm2. The result of the work shows that the misalignment falls within the acceptable limit of 2.0cm as recommended by International Commission on Radiological Protection.

Study by Taha,Atomic Energy Authority - Nuclear Research Center,Radiation Protection Department, Cairo, Egypt & Physics Department, Faculty of Applied Sciences, Umm AlQura University, Makkah, P.Box 715, Saudi Arabia.(2013) ,The X-ray beam alignment was checked using perpendicularity of reference axis with table/Bucky with field size of 20 x 20 cm, 5 mAs, 70 KVp and 100 cm source to detector distance. To ensure within acceptable limits that the x-ray field is of appropriate size and aligned with the image receptor. The X-ray beam alignment was carried out for six machines of the same type and manufacture in AlKhair hospital, Mansora City, Egypt. The beam alignment was calculated.The measured X-ray beam alignment provided to align the center of the X-ray field with respect to the center of the image receptor lower than 2 percent of the source-image receptor distance(SID) as mentioned in (FDA,1999).

And study by Sungita, et al, Nuclear Instrument Maintenance Section, National Radiation Commission, Arusha, Tanzania, Beam alignment and collimation: The RMI beam alignment tool (Model 161B) and collimation test tools were used. The placement of collimator and beam alignment test tool done according to RMI quality assurance handbook. The radiograph done on the 8" x 10" cassette. The exposure parameters to give good picture were selected accordingly. Collimation: If the X-ray field falls just within the image of the rectangular frame there is a good alignment. E.g., if the edge of X-ray field falls on the 1st spot lcm on either side of the line, it shows that X-ray and light field is misalign by 1% of the distance between the X- ray source and the table. The maximum allowable misalignment is 2% of the source to image distance, (S.I.D). Beam alignment: The X-ray beam should be perpendicular to the plane of the image receptor. If the images of the two steel balls on the test tool overlap the central ray perpendicularly or within 1.5° away it is acceptable.Results and discussions: Misalignment of the light field and the x-ray field is a commonproblem for x-ray units surveyed. About 40% of the units tested indicated that the x-ray and light fields are misalign by more than 2% (± 2cm) which is unacceptable . However in most of cases the problem was rectified by the maintenance personnel of the research team. The x-ray beam in some units also showed the central ray is more than 3 degrees away from the perpendicular although they are few units misalign to that extent In some Hospitals, the faulty beam alignment and collimation devices were dismantled and radiograph were done without it which pose unnecessary exposure to the patients.

Other studyQUALITY CONTROL TESTS IN SOME DIAGNOSTIC X-RAY UNITS IN BANGLADESH by Begum et al,2011.Beam Alignment Perpendicularity of the x-ray beam to the image receptor is measured to reduce diagnostic image distortion .In case a grid is used, the distortion may be magnified and this can result in the complete loss of minute details. In the present work, the collimator test tool is placed on the film-cassette. The beam alignment tool is also kept at the center of the collimator test tool. The x-ray tube is directed over the collimator test tool at a distance of 100cm from the film cassette and optical field is collimated at the marked rectangle of collimator test tool. Then film is exposed and developed. Beam alignment is checked at different diagnostic x-ray facilities to determine the perpendicularity of the x-ray beam to the image receptor. In the present investigation, the tolerance limit is defined to be 1.50 from the perpendicular for an FFD of 100 cm. The kVp varied from 50 kVp to 70 kVp, and the mA from 30 mA to 320 mA. The results from the investigation are given in Fig. 5 (b), which indicates that 60% of the facilities are within the limit .The facilities which fell outside the limit should manually adjust their x-ray beam to make it perpendicular to the image receptor in order to reduce radiographic image distortion Congruence between optical and radiation field must be within the limit of 2% of the film-focus distance (FFD) as per quality control protocol to obtain improved quality diagnostic images. Diagnostic x-ray beam should be perpendicular to the image receptor, which prevents radiographic image distortion.

Other study by Taha Radiation Protection Department, Nuclear Research Center, Atomic Energy Authority, Cairo.P.O.13759 Egypt.2010X-ray Beam Alignment The x-ray beam alignment was checked using perpendicularity of reference axis with able/Bucky with field size of 20 x 20 cm, 5 mAs , 70 KVp and 100 cm source to detector distance.The alignment of x-ray machines was investigated using perpendicularity test tool The alignment was ranged from 0.3 to 0.7 cm which is lower than the tolerance level (± 1 cm at 100 cm at FDD).

Other study studies on the status of light beam diaphragms in calabar, effect and implications on radiation protection byEgbe, et al, (2003), The status of Light Beam diaphragms (LDBs) in Calabar, Cross River State were studied using a quality assurance test method to check the beam alignment and collimator accuracy of x-ray equipment in diagnostic centers in Calabar. Results showed an increase in misalignment of the x-ray field and light field with an increase in the light field. The greatest misalignments were 7.9% and 5.6% along the cassette and across the cassette respectively. On the other hand, the least misalignments across and along the cassettes were 0.3% and 1.1% respectively. This indicates an unacceptable status of LBDs in Calabar, and the implication of this in image quality and radiation protection is noted as an undesirable development as it evidently contributes an unwelcome quantity to the radiation dose to the patient population.

Chapter three

3- Materials and Methods:

3.1 Materials:

3.1.1Study sample:

This study include 12 diagnostic radiography department Khartoum state hospitals about the CR system x-ray machine , for 12 x-ray machines from difference manufactures .

This procedure is designed to confirm that the x-ray field and light field are the same.

3.1.2 Equipment

12 x 14 Image receptor

9 pennies

Ruler

3.1.3Procedure

Place the image receptor on the tabletop.

Center to the tube to the image receptor and set the tube at 100cm SID.

check that the tube and the tabletop are perpendicular .

At the center of each edge of the light field place two pennies side by side one penny is placed in the light field and the other penny is placed outside the light Field

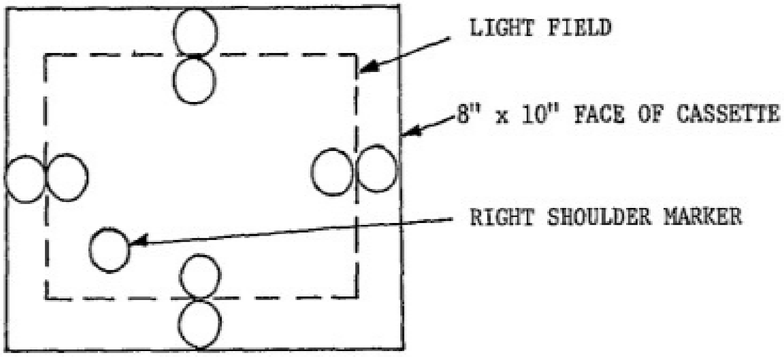


Fig: (3.1) Diagram of the layout for the nine penny test.

Place the ninth penny within the light field to indicate the anode side of the tube and the Bucky handle side of the table.

Set a technique 50kv and 4 mAs and expose the film.

Process the film.

Measure the image.

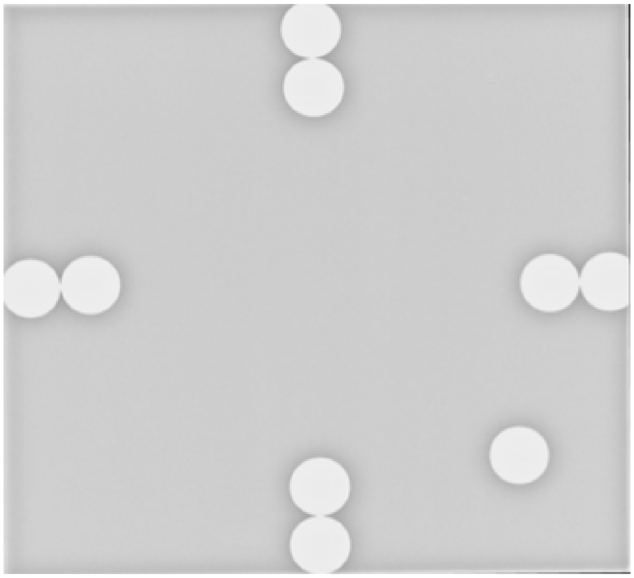


Fig: (3.2) Image of the nine penny test

Record the results.

3.2. Acceptance Parameters

NCRP Report #99 make the following recommendations.

The collimator light to x-ray field must be within ±2% of the SID.

At a 100-centimeter SID, the light field should be within ±2 centimeters.

Note : the width of a penny is approximately 1.8 cm

3.3 Record Keeping

A record should be kept that documents the date of the test, who performed the test, the results of the test, and the corrective action taken.

Note:

When corrective action is taken, the before and after films should be kept on file.

3.4 Analysis:

Misalignments across the cassette (AC1 and AC2) and that along the cassette (AL1 and AL2) were added and recorded as total misalignment TOT AC and TOTAL, as follows: AC1 + AC2 = TOT AC (total misalignment across the cassette) AL1 + AL2 = TOT AL (total misalignment along the cassette) To determine the % misalignment of light versus x-ray field along and across the cassette, the total misalignment was divided by the focus to film distance (100 cm) and multiplied by 100 and in the same film measured the percentage of the center misalignment of the film in the cassette holder and center of the x-ray field at the SID 100 as shown

TOT AC/100 × 100 = % misalignment of light vs. x-ray field across cassette

TOT AL/100 × 100 = % misalignment of light vs. x-ray field along cassette

(CtrMis / 100") 100 = % misalignment of the center of the film in the cassette holder and the center of the x-ray field at an SID of 40 inches. If either of the above is greater than 2%, corrective action is necessary.

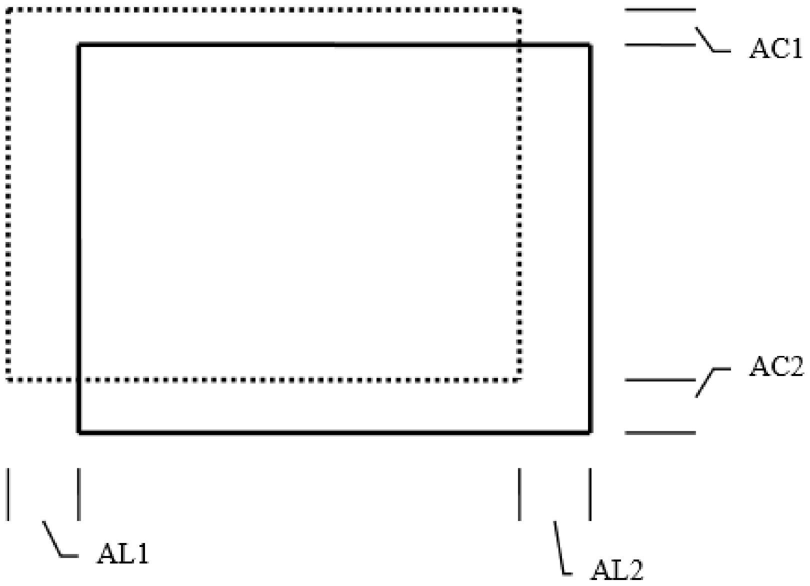
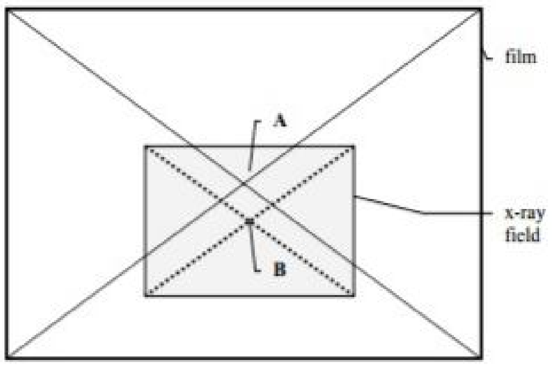


Figure (3.3).Determining the Total Misalignment of the Light Field and the X-ray Field(John, 2001).



Figure(3.4)Determining Alignment of X-ray Field to Cassette Holder.
(John, 2001)

Chapter Four

The Results

4- Results:

This study has been done in the diagnostic department at the 12 hospitals on Khartoum state, for 12 x-ray machines appears different measurement of alignment of x-ray field to cassette holder under the limits, also show the distribution of machines according to manufactures and total misalignments measurements, and Total measurements of alignment of X-ray field to cassette holder in addition to that show beam alignments accuracy in total along cassette and total across cassette moreovershow accuracy of alignment of X-ray field to cassette holder .

Table (4.1): distribution of machines according to manufactures

Manufacture company	Number of machine
Shimadzu	5
Toshiba	2
Fuji film	1
Dong fang	1
Unknown	3

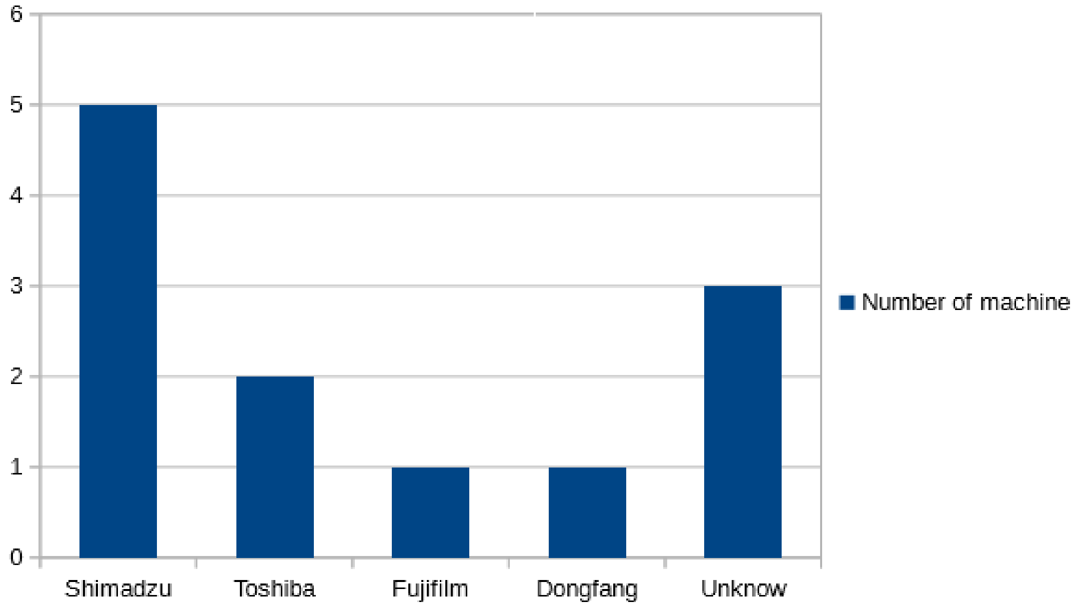


Fig (4.1) distribution of machines according to manufactures.

Table (4.2) total misalignments measurements

No of machine	measurement of alignment		
	Directions	Measurement(cm)	Total(cm)
1	Al 1 Al 2	0.7 0.8	1.5
	Ac 1 Ac 2	1.8 1.8	3.6
2	Al 1 Al 2	0.5 0.5	1
	Ac 1 Ac 2	0.4 0.5	0.9
3	Al 1 Al 2	0.3 0.8	1.1
	Ac 1 Ac 2	0.4 0.5	0.9
4	Al 1 Al 2	0.4 0.4	0.8
	Ac 1 Ac 2	0.1 0.1	0.2
5	Al 1 Al 2	0.1 0.1	0.2
	Ac 1 Ac 2	0.1 0.5	0.6
6	Al 1 Al 2	0.5 0.4	0.9
	Ac 1 Ac 2	2.4 2.4	4.8
7	Al 1 Al 2	0.2 0.1	0.3
	Ac 1 Ac 2	0.2 0.3	0.5

8	Al 1	1.7	2.4
	Al 2	0.7	
	Ac 1	0.3	0.7
	Ac 2	0.5	
9	Al 1	1.1	1.7
	Al 2	0.6	
	Ac 1	1.4	2.6
	Ac 2	1.2	
10	Al 1	0.5	0.7
	Al 2	0.2	
	Ac 1	1	2
	Ac 2	1	
11	Al 1	0.6	0.8
	Al 2	0.2	
	Ac 1	0.4	0.7
	Ac 2	0.3	
12	Al 1	0.1	0.2
	Al 2	0.1	
	Ac 1	0.4	1.1
	Ac 2	0.7	

AL1+AL2: Total along cassette misalignment in cm

AC1+AC2: Total across cassette misalignment in cm

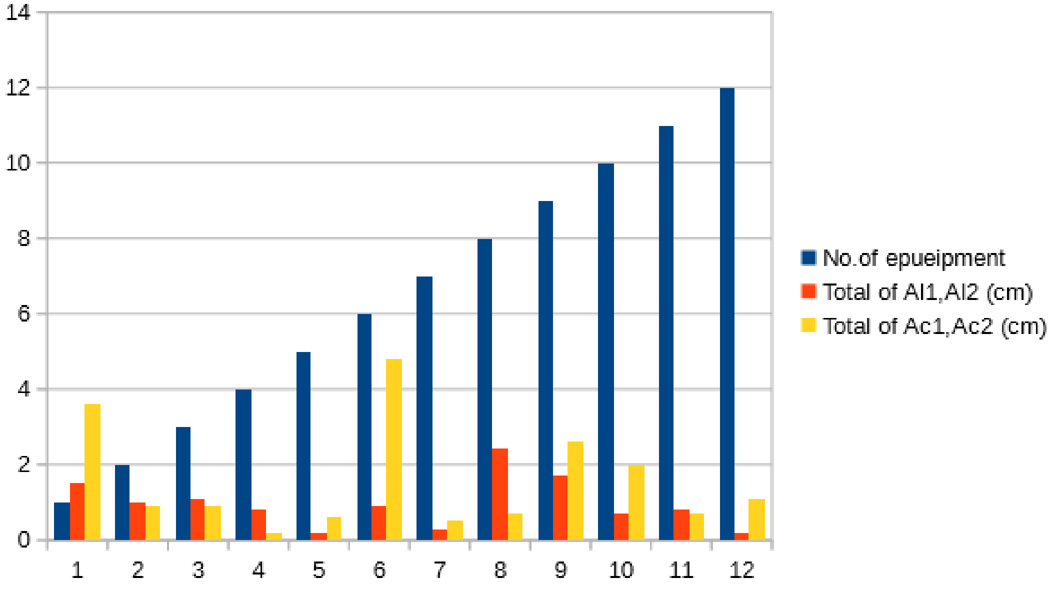


Fig (4.2) Total misalignments measurements for along cassette &across cassette

Table (4.3) Total measurements of alignment of X-ray field to cassette holder.

No of machine	Alignment of central ray (cm)
1	0.2
2	0.8
3	1.4
4	2.4
5	0.5
6	3.2
7	1.5
8	1.4
9	0.1
10	0.3
11	0.8
12	0.2

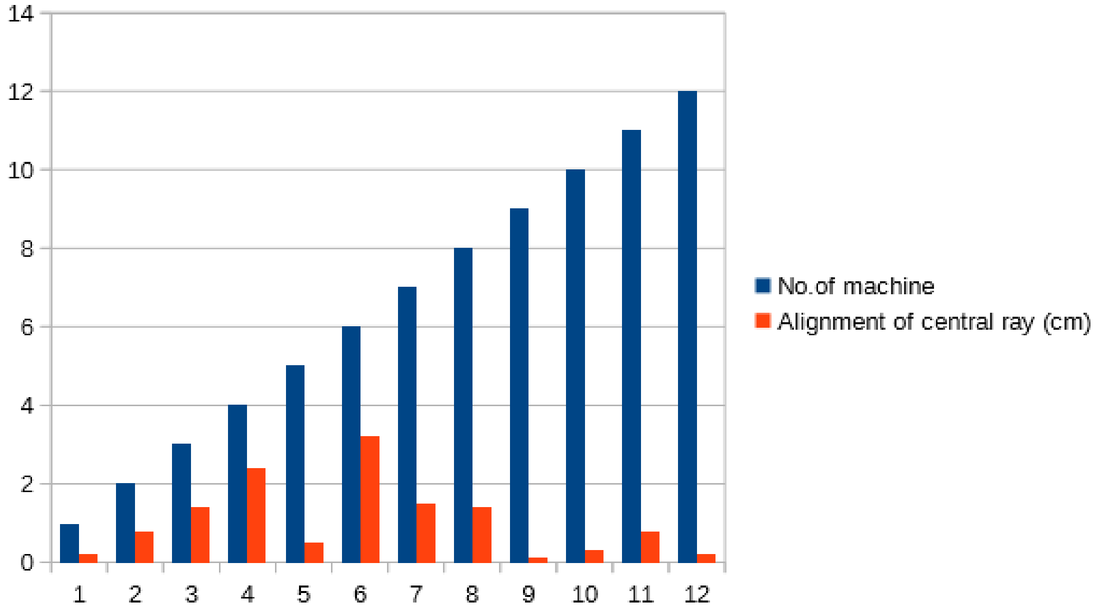


Fig (4.3) **Total measurements of alignment of X-ray field to cassette holder.**

Table (4.4) show beam alignments accuracy in total along cassette.

Classifications	Number of machines	Percentage
Acceptance	11	91.7%
Un acceptance	1	8.3%
Total	12	100%

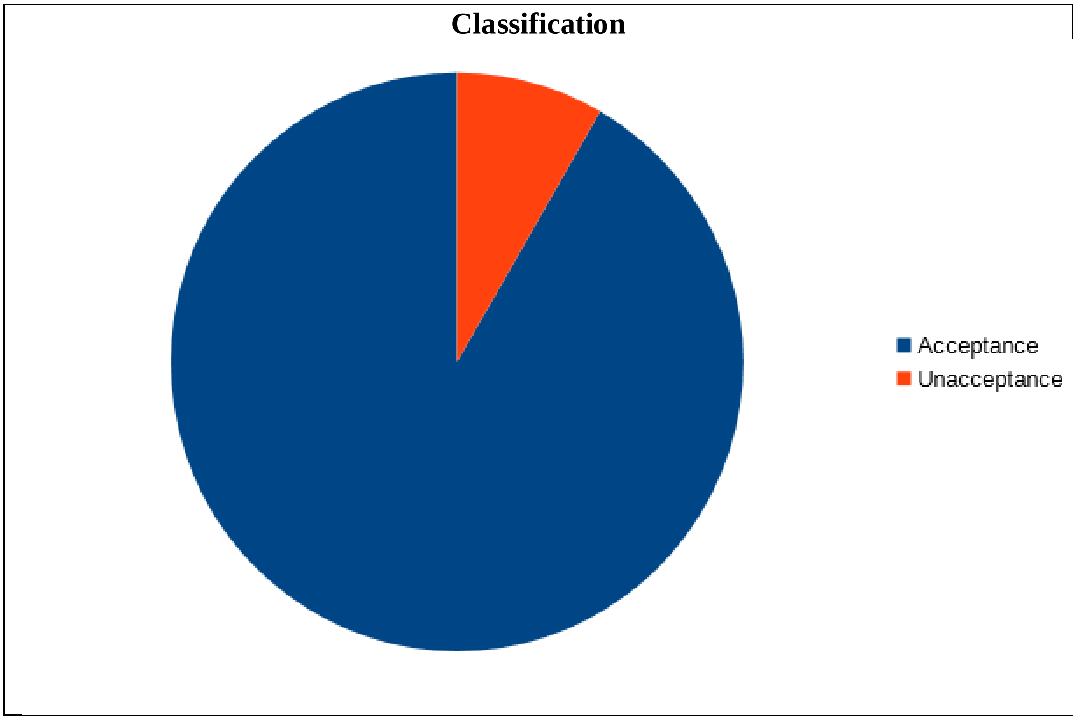


Fig (4.4) show beam alignments accuracy in total along cassette.

Table (4.5) show beam alignments accuracy in total across cassette.

Classifications	Number of machines	Percentage
Acceptance	9	75%
Un acceptance	3	25%
Total	12	100%

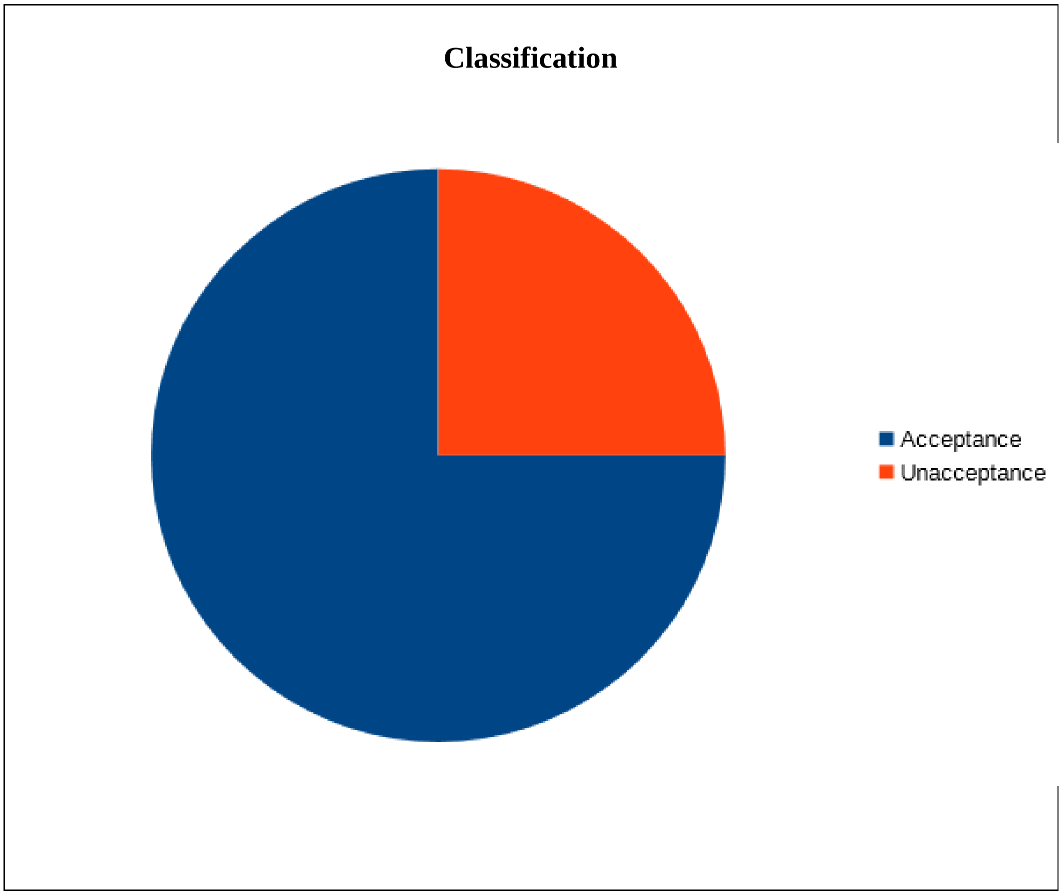


Fig (4.5) **show beam alignments accuracy in total across cassette.**

Table (4.6) show accuracy of alignment of X-ray field to cassette holder

Classifications	Number of machines	Percentage
Acceptance	10	83.3%
Un acceptance	2	16.7%
Total	12	100%

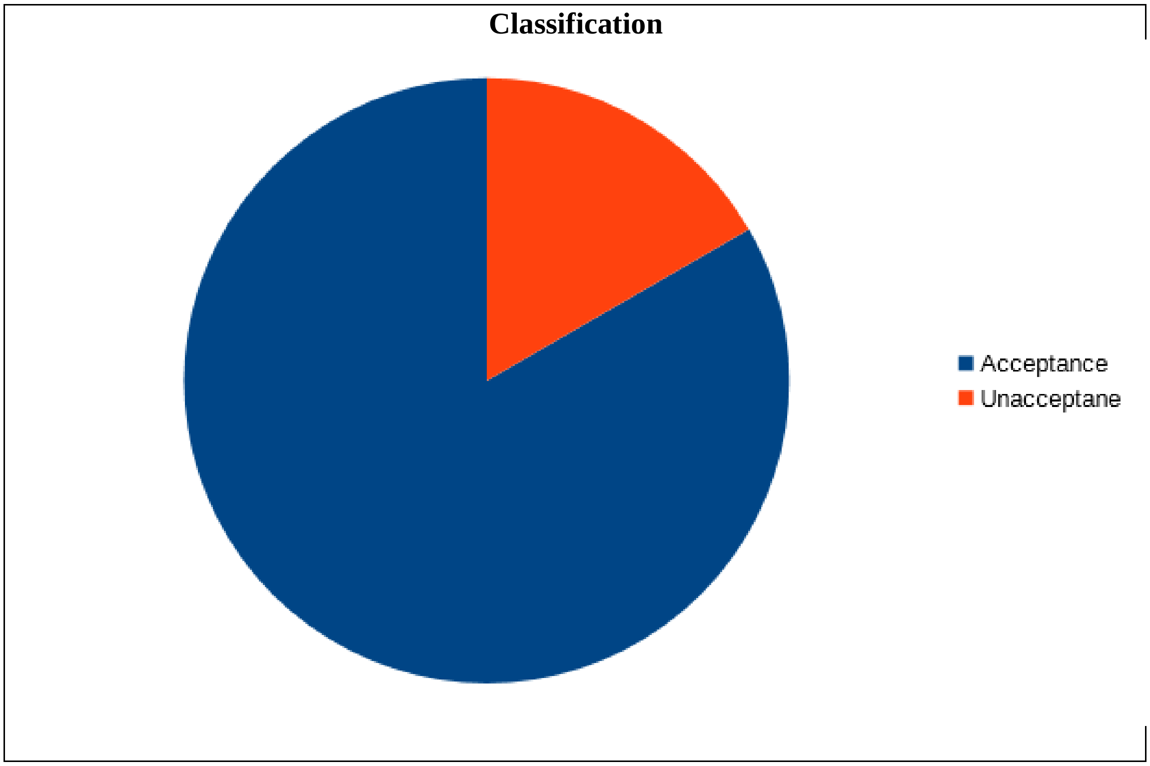


Fig (4.6)show accuracy of alignment of X-ray field to cassette holder

Chapter Five

5.1 Discussion:

This study was done department diagnostic for x-ray tube beam alignment in Khartoum state.

The study involved 12 departments of x-ray machines in 12 hospitals.

According to NCRP & CFRthe quality control ofx-ray tube beam alignment in along cassette and across cassette and central ray cannot exceed from 2% focal film distance.

This study showed there is high percentage of light field and x-radiation field congruency about 91.7% in along cassette just 8.3% unacceptable(2.4) see table (4.2), and 75% in across cassetteonly 25%unacceptable(3.6,4.8,2.6) see table (4.2) too. Also 83.3% in central ray and about 16.7% unacceptable (2.4, 3.2) see table (4.3).

Compare our study with previous studiesstudy by N.B Akaagerger et al, (2015), Evaluation of Quality Control of Beam Alignment and Collimator Test Tools on Diagnostic X-Ray Machines inMakurdi, Benue State-Nigeria for two major Hospitals.

Hospitals A and B were checked using collimator and beam alignment test were used to measure the degree of misalignment of the target points, Hospital A was shown to have a misalignment of 0.2cm at 60kVp, 10mAs, 100cm FFD using a film size of 10x8cm2 while Hospital B had a misalignment of 0.6cm at 25mAs, 81cm FFD using a film size of 10x8cm2.Study by Taha.M.T,AtomicEnergy Authority - Nuclear Research Center,Radiation Protection Department, Cairo, Egypt

&Physics Department, Faculty of Applied Sciences, Umm AlQura University, Makkah, P.Box 715, Saudi Arabia

The measured X-ray beam alignment provided to align the center of the X-ray field with respect to the center of the image receptor lower than 2 percent of the source-image receptor distance(SID)

And study by Y.Y.SUNGITA, et al, Nuclear Instrument Maintenance Section, National Radiation Commission, Arusha, Tanzania, Beam alignment and collimation.

About 40% of the units tested indicated that the x-ray and light fields are misalign by more than 2% (± 2cm) which is unacceptable .

StudyQUALITY CONTROL TESTS IN SOME DIAGNOSTIC X-RAY UNITS IN BANGLADESH by M. Begum et al,2011.

Beam alignment is checked at different diagnostic x-ray facilities to determine the perpendicularity of the x-ray beam to the image receptor.which indicates that 60% of the facilities are within the limit .

Study by T.M.Taha Radiation Protection Department, Nuclear Research Center, Atomic Energy Authority, Cairo.P.O.13759 Egypt.2010

The alignment of x-ray machines was investigated using perpendicularity test tool The alignment was ranged from 0.3 to 0.7 cm which is lower than the tolerance level (± 1 cm at 100 cm at FDD)

Study studies on the status of light beam diaphragms in calabar, effect and implications on radiation protection byN. O. Egbe, et al, (2003),check the beam alignment and collimator accuracy of x-ray equipment in diagnostic centers in Calabar. Results showed an increase in misalignment of the x-ray field and light field with an increase in the light field. The greatest misalignments were 7.9% and 5.6% along the cassette and across the cassette respectively. On the other hand, the least misalignments across and along the cassettes were 0.3% and 1.1% respectively.

As we notice that most of the previous studies give us acceptable result except few of them not acceptable and this indicator that they apply quality control of x-ray machine. And when we apply QC it will help to improve the image quality and also reduce the dose to the patient.

5.2 Conclusion:

Not applying the quality control program to the x-ray machine will contribute deterulationof image quality and interpretation of the image which can lead to repetition of the image and consuming a lot of films and increase dose to the patients.

And by testing the alignment of x-ray tube in Khartoumhospitals and we found out that the alignment is 91.7% & misalignment is just 8.3% in along cassette, and 75% in across cassette 25% misalignment .in the central ray the alignment reached 83.3 % & misalignment 16.7%.

5.3 Recommendation:

We recommend that the quality control safety of machines of x-ray help us to make sure that the device performed in a proper way and will facilitate the repair, and they must be regular evaluation to x-ray machines.

I hope in the future studies to perform quality control tests to the x-ray machines.

5.4 References:

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Y.Y.SUNGITA, S.L.MDOE, J. NGATUNGA, A.E.KITOSI, W.E MUHOGORA Nuclear Instrument Maintenance Section, National Radiation Commission, Arusha, Tanzania.QUALITY ASSURANCE FOR DIAGNOSTIC X-RAY MACHINES IN TANZANIA,