Chapter One:

INTRODUCTION

1.1. Introduction:

Radiation protection in pediatric radiology deserves special attention as children are supposed to be more sensitive to radiation than adults. United Nation Scientific Committee on Effects of Atomic Radiation (UNSCEAR) has reported that children exposed to radiation at an age below 5 years are twice to 3-folds sensitive when compared with adults. It is therefore, important that radiation dose to children arising from diagnostic medical exposure to be minimized. This work motivated by the increasing of radiation risk to infants and children, particularly in a country with a lower health-care infrastructure such as Sudan. In Sudan, as in many other developing countries, no much data are available on radiation doses in diagnostic radiology and pediatric X-rays examinations in particular. Thereby Comparison with reference doses and previous studies should help optimizing radiographic examinations in these hospitals. The results presented will serve as a baseline data needed for deriving reference dose levels (DRLs) for pediatric X-rays examinations in Sudan.

The first radiation induced cancer in human was reported in 1902 (Thomas E. johnson et al, 2012). When skin cancer was observed on the hand of a radiologist working with X-rays. In a few years, a large number of such skin cancers had been observed, and the first report of leukemia occurring in five X-rays photographers appeared in 1911 (Thomas E. johnson et al, 2012). Consequently, the interest in radiation Risk was increased. However, the effects of the atomic bomb in Japan are the most important source of information on human whole-body irradiation. For risk estimates the variation of age, sex and quantity of people give a much better possibility to estimate the effects of the dose received. The number of X-rays facilities in medicine increased rapidly with time. And it is well known that diagnostic X-rays is the largest artificial source of radiation exposure to the general population, recent estimates by the national radiation protection board (NRPB) in the united kingdom have set the contribution from patients undergoing X-rays examination to nearly 90% of the total effective dose from all artificial sources in the UK for example (E P AO R I A, 2006). With this increases in quantity of X-rays examinations, a growing quantity of cancer cases can be expected, despite the fact that transformation from analogue to digital system can give lower doses.

In pediatric this increase of X-rays examinations is more risky, Young individuals have a longer life expectancy and their developing tissues are more radiosensitive. The risk factor for children for development of cancer is four to five times that of adults (40-50) years of age (Reilly Sutton, 1997). The stochastic risks of carcinogenesis effects can be estimated through the effective dose. This is central in radiation protection process to realize radiation risks for different investigations. The effective dose can be obtained by using an anthropomorphic phantom loaded with TLD dosimeters located at anatomical positions corresponding to radiosensitive organs, or by using montecarlo method to simulate the interaction of X-rays in an Anthropomorphic mathematical phantom. Dose-area product (DAP) is an easily available measurement, but Information about the Radiological risks cannot be deduced directly from this value, since the patient age and size, Beam position and effect of scattered radiation are not taken into consideration. The effective Dose which is a weighted sum of equivalent doses in selected organs is measurable in Phantoms, but difficult in the human body. Consequently, the effective dose can be measured by combining relatively simple measurements of DAP, and calculated dose conversion factors. The risk related with exposure to X-rays is dependent on the characteristics of the exposed Individual, The size, age and sex of the individual influence the absorbed dose distribution in the organs. Nevertheless, little dosimeter data and conversion factors exist for pediatric examinations due to great size variation despite the close relationship between risk and age (Thomas E. Johnson et al, 2012).

The prevention of the potential hazardous effect of ionizing radiation has been a critical focus and great concern, despite their valuable contribution of ionizing radiation in medical imaging to diagnosis and subsequent treatment of various disease entities (IAEA, 2007). Radiation exposure, either from radiation accident or medical X-rays examination at the early stage of life usually results in a likelihood of two or three fold increase in lifetime risk for certain detrimental effects, including solid cancer, compared with that for adult (IAEA, 2007). Radiation protection in pediatric radiology requires special attention than in adult radiology because children are more sensitive to radiation and they are at higher risk than adults. The higher risk is due to longer life expectancy in children for any harmful effects of radiation to manifest and the fact that developing organs and tissues are more sensitive to the effects of radiation (ICRP, 1990). To prevent the detrimental effects of ionizing radiation, several international bodies on radiation protection have strictly stipulated three fundamental principles as the bedrock of sound radiological protection, namely justification, optimization, and the application of dose limits. They have also provided a range of reference dose in all population, including pediatric age group (IAEA, 2007). It is known that patient doses from X-rays examinations vary widely, even for the same projection. The dose variation may be due to patient weight, exposure factors, radiological technique, focus to film distance (FFD), film-screen speed, equipment type and processing performance.

This variability can be reduced through quality assurance program in hospitals and thereby, providing diagnostic reference dose levels for various radiological procedures through Entrance Skin Dose (ESD) and effective dose calculations (E P AO R I A, 2006).

In Sudan, most diagnostic X-rays centers do not have special X-rays unit for pediatric patients, and X-rays operators sometimes used exposure parameters and radiographic techniques that are not appropriate for children. Although, there is no consensus on the optimal radiographic techniques that could be used on patients, however, if radiographic parameters are optimized, a significant reduction in ESD to patients would be achieved. The estimates of ESD specific to pediatric radiology are very crucial as the skin of children is tender and can easily be damaged by excessive radiation dose.

Also, knowledge of entrance skin dose is needed to formulate national diagnostic reference level for optimizing radiation protection of patients in pediatric radiology (ICRP, 1990). Despite the fact that conventional radiography is one of the most requested diagnostic imaging modality in Sudan, which may be due to X-rays examination being widely available, cheap and quick to acquire. There is a paucity of studies on diagnostic dose references in Sudan.

1.2. Aims of the work:

The aim of this study is to investigate radiation doses in pediatric chest radiology and analyze factors that affect radiation doses, that is, by assessing the exposure parameters selected for X-rays examinations of pediatric patients in two largest teaching hospitals in Khartoum State, Sudan, to estimate the entrance skin dose (ESD) delivered to pediatric patients during chest x-ray examination and to compare this dose with the previous studies and international literature.

1.3. Over view of the thesis:

This thesis consists of five chapters. In chapter one the general introduction, biological effects of radiation, principles of radiation protection, and the objectives of this study are presented. In chapter two the literature review, ionizing radiation, production and properties of x-rays, radiation quantities and units are presented. Materials and methods used are described in chapter three Results are provided in chapter four. Conclusions, discussion and recommendations are given in chapter five.

Chapter Two

BACKGROUND AND LITERATURE REVIEW

X-rays are electromagnetic waves with wavelength of 10^4 pm (picometer); a picometer is equal to 10^{12} m. The classical way of producing X-rays consists in accelerating a high voltage electrons beam in an X-rays tube, and then allows them to collide with a target metal with high atomic number.

2.1. Basic elements of an X-rays source assembly:

There are two main elements in a standard X-rays device, namely, the X-rays generator and the X-rays tube. In this section, we discuss briefly the important role of the X-rays generator then we introduce the main components of the X-rays tube.

2.1.1. X-rays generator:

The important role of the X-rays generator is to provide the X-rays tube with current to heat the cathode filament that produces the electrons beam, and the voltage that accelerates the electrons toward the target metal (anode). The generator also serves as an automatic control of the X-rays exposure and beam hardness by controlling the voltage which is applied between the filament and the target metal (Jaypee et al, 2001).

2.1.2. X-rays tube:

An X-rays tube is made of different elements as shown in Fig. 2.1. The cathode which is the source of electrons beam. The anode which is impacted by the electrons beam to emit X-rays. Surrounding glasses for the X-rays tube to allow the electrons beam to travel in vacuum. Also this housing increases the durability of the tube. Shielding materials protect the environment against scattering radiation, and the cooling system dissipates the heat produced within the tube.

The cathode and the anode are the main components of the X-rays tube. The cathode of the X-rays tube includes filament and an associated circuit for current supply. The filament is usually made of tungsten because it has relevant characteristics such as high melting point nearly 3370 C, slow filament evaporation, a very low arcing, and a minimum deposit of tungsten on glass (Jaypee et al, 2001). The anode of the X-rays tube consists of the target metal for fast electrons beams. Usually this target is also in tungsten. However rhenium, molybdenum and graphite can also be used depending on the purpose of the specific tube. For example, for low energy mammography, molybdenum target is often used. The surface of the anode that impacted by the electrons beam is known as the focal spot. To reduce the heat capacity of the focal spot, rotational anode has been used in new X-rays devices. Modern X-rays tubes have two filaments with different characteristics giving more advantages: a long filament which uses high current but gives low resolution, and a short filament which uses low current but gives high resolution (Jaypee et al, 2001).

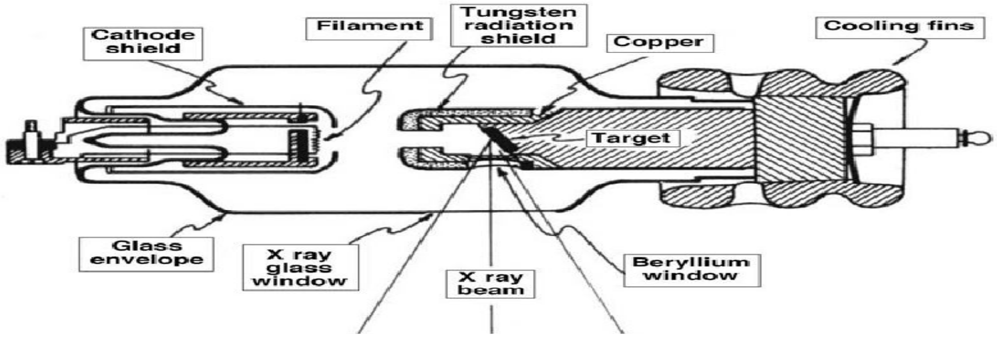


Figure (2-1) shows the x-ray tube.

2.2. X-rays beams:

The classical way of producing X-rays can be done through two different techniques. The first technique is by suddenly decelerating electrons beam upon collision with the target metal. These X-rays are called Bremsstrahlung (the German word for braking radiation). The second technique is by bombarding the target material with sufficient energy to knock electrons out of the inner shell of the atoms. Electrons make a transition from higher energy level to lower level and the difference of energies is emitted as X-rays. These X-rays are called characteristic X-rays (James E. Martin, 2006). Hence, the X-rays beam produced in the tube can be divided into two groups, characteristic X-rays and Bremsstrahlung X-rays. Characteristic X-rays are due to coulombic interactions between the incident electrons beam and the orbital electrons of the target material. The bombarding electrons can put out electrons from the inner shells of the target atoms producing vacancies. Electrons from the higher level drop down to all these vacancies, thereby emitting X-rays with precise frequencies associated with the difference between the atomic energy levels of the target material (James E. Martin, 2006), (IAEA, 2005). Characteristic X-rays spectrum shows discrete energy levels with peaks as presented in Fig 2.2. These peaks occur when vacancies are produced in the K-shell (n=1) of the atom and electrons drop down to all those vacancies. X-rays yield by transitions from L-shell (n=2) to K-shell (n=1) levels are called K X-rays. X-rays yield by transitions from M-shell (n=3) to k-shell (n=1) levels are called K X-rays (James E. Martin, 2006).

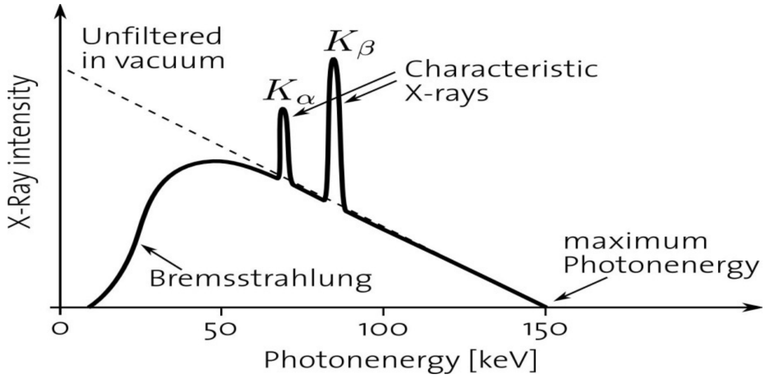


Figure 2.2: Characteristic X-rays spectrum

Bremsstrahlung X-rays are produced when fast electrons beam with high energy are decelerated or braked when they are fired at a metallic target. Accelerated electrons give out electromagnetic radiation in a continuous distribution. This radiation becomes more intense and shifts toward higher frequencies when the energy of the bombarding electrons is increased as seen in Fig.2.2. Bremsstrahlung X-rays can be produced in a wide energy spectrum depending upon the degree of braking or detection that the accelerated electrons experience from their interaction with the target nuclei (IAEA, 2005).

2.3. Interaction of X-rays with matter:

X-rays interactions with matter are very important in diagnostic examination for many reasons. For example, the X-rays photographs are produced by particular interactions of X-rays with the structure of human body. As X-rays are photons, when an X-rays beam passes through material (e.g. human body), there are three possible fates awaiting each photon: It can penetrate the section of the matter with no interaction, it can interact with the section of the matter and be absorbed completely by depositing its energy, and also it can interact with the section of the matter and be scattered or deflected from its original direction and hence deposits part of its energy. These three possibilities yield five types of interactions between X-rays photon and matter. In this section we discuss briefly these interactions (James E. Martin, 2006).

2.3.1. Coherent scattering:

Coherent scattering, also known as classical scattering, occurs when a low energy X-rays photon interacts with the whole atom. The photon is scattered without change in the internal energy of both the interacting atom and the X-ray photon. Mainly this scattering happens in the forward direction. Although this type of interaction happens at low energy photons, it is generally not significant in most diagnostic procedures. However, it may contribute to graying the image called film fog (blurring in the image) (James E. Martin, 2006), (IAEA, 2007)

2.3.2. Photoelectric effect:

Photoelectric effect, also known as Photo effect, takes place when an X-rays photon interacts with a tightly bound orbital electron (from the inner shell). This photon attenuates and disappears while the orbital electron which absorbs the photon energy ejects from the atom as a photo-electron with a kinetic energy equal to the difference between the photon energy and the binding energy of the electron. This kinetic energy is given by:

$$E_k = hv - E_b;$$

Where v is the frequency of the incident photon, h is Planck's constant and E_b is the binding energy of the electron within the atom. The energy transfer here is a two-step process. First, there is the photoelectric interaction in which the photon transfers its energy to an electron. Secondly, this electron deposits its energy in the surrounding matter. Photoelectric interactions are most probable when the electron binding energy is slightly less than the incident photon energy. This implies that the photon energy is divided into two parts: a part which is used to overcome the electron binding energy and the remaining energy is transferred to the electron as kinetic energy (James E. Martin, 2006), (Reilly Sutton, 1997).

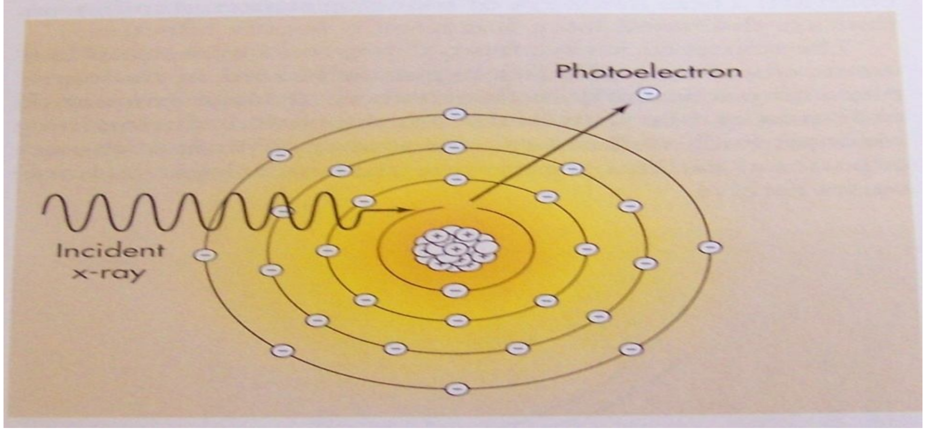


Figure 2.3: Photoelectric effect (James E. Martin, 2006).

2.3.3. Compton scattering:

Compton scattering also known as inelastic scattering, is the predominant interaction of X-rays photons in the diagnostic energy range (30-150) keV with soft tissue. This interaction most likely occurs between an X-rays photon and the outer shell electrons (valence electrons). The electron which absorbs part of the photon's energy is ejected from the atom. The photon is scattered with some reduction in energy with scattering angle. This change in photon energy according to Compton equation is represented as a deviation in the wavelength as follows:

$$\Delta\lambda = \lambda_c(1 - \cos\theta)$$

Where λ_c is the Compton wavelength of the electron, θ is the scattering angle. According to the laws of conservation of energy and momentum, the energy of the incident photon E_0 is equal to the sum of the scattered photon energy $E_{scatter}$ and the kinetic energy of the ejected electron E_{eject} (Reilly Sutton, 1997).

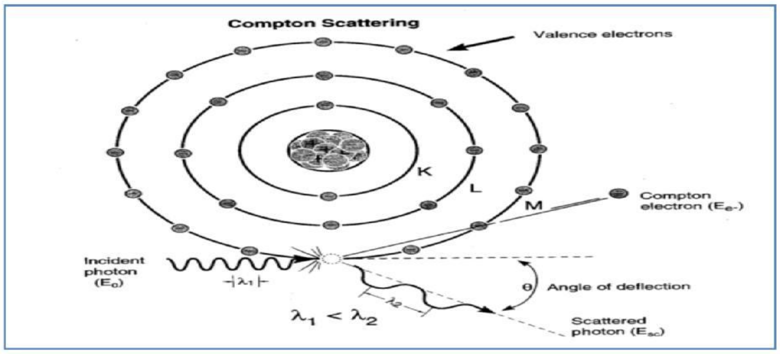


Figure 2.4: Compton scattering (James E. Martin, 2006).

2.3.4 Pair production:

This interaction takes place when a high energy photon (> 1.02 MeV) interacts with the nucleus in such a way that its energy is converted into matter. This yields a pair of particles, an electron-positron pair in the nuclear Coulombic field and the photons disappears. The pair is produced with a combined kinetic energy equal t0:

$$E_k = hv- 2m_eC^2;$$

Where m_e is the mass of the electron and c is the speed of light. Since mass is produced out of the photon energy in the form of an electron-positron pair, pair production has an energy threshold (minimum energy required for the effect to happen) of $2m_eC^2= 1.02$ MeV. This means that the probability for the pair production is zero for photon energies below the threshold and increases rapidly with photon energy above the threshold. Pair production is not encountered in diagnostic procedures due to its high energy threshold. However pair production is very useful for positron emission tomography (PET) in nuclear medicine (James E. Martin, 2006).

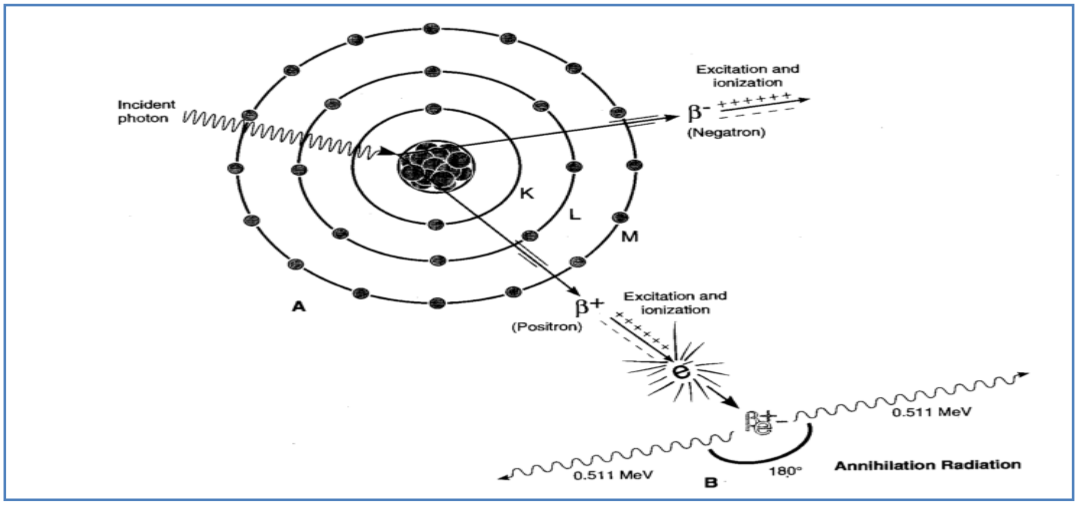


Figure (2.5) show Pair Production

2.3.5. Photodisintegration:

High energy X-rays photons with energies above 10 MeV can escape interacting with both the electrons and nucleus electrostatic fields. These photons interact with the nucleus and are absorbed by the nucleus. This excites the nucleus and results in the release of a nucleon or other nuclear material. This process is called photodisintegration. Like in pair production, the high energy needed to cause this interaction makes it less important in diagnostic radiography (Reilly Sutton, 1997), (IAEA, 2007).

2.4. Effects of ionizing radiation:

Ionizing radiation is known to cause damage. High radiation doses tend to kill cells, while low doses tend to damage or alter the genetic code (DNA) of irradiated cells. The biological effects of ionizing radiation are divided into two categories: Deterministic and Stochastic effects.

2.4.1. Deterministic effects:

Health effects whose severity depends on radiation dose (usually with a threshold) and dose rate is called deterministic effects. Some interventional procedures with long fluoroscopy time and multiple image acquisition (e.g. percutaneous coronary intervention, radio-frequency ablation, etc) may give rise to deterministic effects in both staff and patients. The deterministic effects include nausea, hair loss, damage to the blood and bone marrow, damage to the intestines, and damage to the central nervous system. Table 1-1 shows the potential effects of radiation. Table 1-1 Potential effects of x-ray exposures on reaction of skin and lens of the eye with data from ICRP population 85. Table 2-1 Potential effects of x-ray exposures on reaction of skin and lens of the eye with data from ICRP population 85 (MuthanaAlGhazi, 2007).

Injury	Threshold Dose to Skin (Sv)	Minutes fluoro at 0.02 Gy/min	Minutes fluoro at 0.2 Gy/min
Transient erythema	2	100	10
Permanent epilation	7	350	35
Dry desquamation	14	700	70
Dermal necrosis	18	900	90
Telangiectasia	10	500	50
Lens/Cataract	> 5	>250 to eye	>25 to eye

2.4.2. Stochastic effects:

The effects whose frequency is an increasing function of dose, usually without threshold, such effects are seen at some time after irradiation, possibly decades later. Stochastic effects include cancer and leukemia.

Table 2-2 shows the annual risk of death compared with cancer from radiation exposure.

Causes	Risk of death per year
Smoking 10 cigarettes/day	1 in 200
Natural causes (40 year old)	1 in 850
Accidents on road	1 in 9500
Accidents at work	1 in 43.500
Cancer from radiation exposure of 1 mSv	1 in 25.000

2.5. Radiation protection methods:

There are three basic methods to keep the radiation dose in the patients, workers and the public as low as reasonably achievable. They are namely, minimization of the time of exposure, maximization of the distance to the radiation source, and use of appropriate shielding material to protect against the scatter radiation (e.g, lead Pb and aluminum Al). These three steps help to achieve the so-called ALARA Principle, which stands for As Low As Reasonably Achievable (James E. Martin, 2006).

2.6. ALARA principle:

The ALARA Principle consists in maintaining the radiation dose as low as reasonably achievable taking into consideration economics and social constraints. The goal of the ALARA principle is to keep the radiation dose as far below the occupational dose limits, which is the annual dose limits to the workers within the ionizing radiation areas (50 mSv annual or 10 mSv age for accumulative) (Thomas E. johnson et al, 2012). The ALARA principle is based on the Linear Non-Threshold (LNT) dose effect hypothesis, which assumes that the risk of developing cancer is associated with long term radiation exposure. The LNT hypothesis assumes that the high doses of ionizing radiation associated with observed injurious effects in humans may be used to predict the effects of low doses. According to the LNT hypothesis, any dose of ionizing radiation, no matter how small it is, has some detrimental effect and each incremental increase in the dose increases the probability of detrimental effects associated with that exposure (James E. Martin, 2006), (E P AO R I A, 2006).

2.7. Medical applications of X-rays:

Medical imaging using X-rays began with the first photograph that Rontgen took from his wife's hand. Since then, X-rays imaging allows improvements in diagnosis and treatment of numerous medical issues. There are different medical imaging procedures; each of them uses a different technique and technology which gets improved upon time. They include radiography (conventional X-rays and mammography), Fluoroscopy, and computed tomography. All these modalities have the same basic principle. When an X-rays beam passes through the human body, a portion of the beam is either absorbed or scattered by the internal structure (soft tissue or bones), and the remaining X-rays beam which passes through the body is transmitted to a detector (e.g. a film or a computer screen). This transmitted part is very important in medical imaging as it forms the image (James E. Martin, 2006), (Reilly Sutton, 1997).

2.7.1. Radiography:

Radiography is an imaging technique that uses X-rays to view the internal structure of a non uniformly composed and opaque object (a non-transparent object with a variation in density and composition) such as the human body. Radiography is used in many types of medical examinations and procedures where a record of a static image is desired. Examples of radiology include, dental examination, verification of correct placement of surgical markers prior to invasive procedures, mammography, orthopedic evaluations, spot film or static recording during fluoroscopy, and chiropractic examinations. Mammography is a special type of radiography used for imaging the internal structures of the breast. This technique is the most reliable method of detecting breast cancer even in the early stage. In mammography we use low dose imaging at low energies to detect tumors in the breast with high resolution, approximately 40 micrometer with best soft tissue contrast at low energies (James E. Martin, 2006).

2.7.2. Fluoroscopy:

In fluoroscopy a continuous X-rays imaging is displayed on a monitor (a fluorescent screen or phosphor). This allows real-time monitor of the procedure or passage of a contrast agent (dye) through the body. This live X-ray view of the patient can be used to get real-time imaging and for aligning the patient to the X-ray tube for imaging (Jaypee et al, 2001). The main disadvantage of fluoroscopy is that it can result in relatively high radiation dose. Especially, in the case of complex intervention procedures e.g. during the operation to put some devices inside the body. However to reduce this disadvantages, the radiation dose modern systems use image intensifiers and a closed circuit TV system (James E. Martin, 2006).

2.7.3. Computed tomography:

Computed tomography (CT) was first introduced by Godfrey Hounsfield in 1971. It is a special form of tomography in which a computer is used to make a mathematical reconstruction of a tomographic plane or slice. Hounsfield first machine was designed to study the head, later it has been modified to scan any part of the human body. The CT scan helps radiologists to visualize the cross sectional view of the organ on a TV screen. This allows physicians to delineate the tumor and normal structures accurately using axial homographic images of the patient's anatomy. CT system provides gray scale display of the linear attenuation coefficient which is closely related to the density of human body tissue. CT imaging evolved from the conventional planar radiography. In X-rays film imaging, the three-dimensional anatomy of the patient is reduced to a two dimensional attenuation projection image and the depth information of the structures is lost. However in CT imaging, several attenuation projections for a volume of tissue are acquired at different angles. Then the set of projection images are reconstructed using Filtered Back Projection Algorithm in order to generate a two-dimensional attenuation cross section for the anatomy of the patient. To acquire the projection images, a rotating X-rays tube and a detector are put on opposite sides of the patient. Early CT scanners used pencil to acquire projection images. Modern CT scanners have a stationary or rotating detector with a rotating fan-beam X-rays tube (James E. Martin, 2006), (MuthanaAlGhazi, 2007).

There are two types of CT scanning used in CT machines nowadays, namely, axial scanning and helical scanning. In the axial scanning, the patient table moves step by step acquiring sets of projection images for each slice. In the helical scanning, the patient table moves continuously while the X-rays tube acquires a series of projection images for each helical path of the patient. To reconstruct a cross sectional planar image, these helical data are interpolated to give axial plane projection data before reconstruction (James E. Martin, 2006).

The reconstructed CT image is a two-dimensional matrix of numbers. Each pixel corresponds to a spatial location in the image and in the patient. Usually this matrix is 512 pixels wide and 512 pixels tall. The numerical value in each pixel represents the attenuation coefficient (μ_{pixel}) as a gray level in the CT image. These numbers are called Hounsfield units (HU) or CT numbers. Hounsfield matrix gives the linear attenuation values normalized to the attenuation of water (μ_{water}). This normalization can be written as:

$$\text{CT Number (HU)} = 1000 \times \frac{\mu_{pixel} - \mu_{water}}{\mu_{water}}.$$

The CT number gives an indication on the type of the tissue. Water has a CT number of zero, while negative CT numbers are typically for air spaces, lung tissues and fatty tissues; the positive values are for bones. The critical diagnostic decisions are based on the CT number of particular region of interest. Also attenuation values given by CT numbers can be used to calculate the dose delivered to the tumor in radiotherapy treatment plan (James E. Martin, 2006).

2.7.4. Other applications of X-rays:

Apart from medical discipline, many other applications of X-rays exist. In industry, X-rays are used to detect flaws non-destructively in casting that are inaccessible to direct observation; this mechanism is called non destructive test. X-rays microscope is capable of magnifying X-rays absorption images so as to resolve features on scales smaller than 40 nm. This resolution is nearly about five times greater than that achieved by the best visible light microscope. In agricultural industries X-rays are used to irradiate some foods to inhibit selectively the growth of bacteria. In material science and engineering, X-rays diffraction technique which is also known as X-ray crystallography allows the determination of the crystal structures in different materials, organic, inorganic and biological systems. We can use X-rays to examine and analyze old paintings and for archaeological studies (Jaypee et al, 2001). X-rays are also used in security, for instance in airports around the world for quick checking the contents of the airline baggages.

2.8. Image quality:

Image quality is a general concept that applies to all types of images. It applies to medical images, photography, television images, and satellite reconnaissance images. Quality is a subjective notion and is dependent on the function of the image. In radiology, the outcome measure of the quality of a radiologic image is its usefulness in determining an accurate diagnosis. It is important to establish at the outset that the concepts of image quality are fundamentally and intrinsically related to the diagnostic utility of an image. Large masses can be seen on poor-quality images, and no amount of image fidelity will demonstrate pathology that is too small or faint to be detected. The true test of an imaging system, and of the radiologist that uses it, is the reliable detection and accurate depiction of subtle abnormalities. With diagnostic excellence as the goal, maintaining the highest image fidelity possible is crucial to the practicing radiologist and to his or her imaging facility (IAEA, 2005).

2.9. Radiation Quantities:

Radiation measurements and investigations of radiation effects require various specifications of the radiation field at the point of interest. Radiation dosimetry deals with methods for a quantitative determination of energy deposited in a given medium by directly or indirectly ionizing radiations. Number of international accepted quantities used for radiation measurement and radiation protection has been defined by the International Commission for Radiation Protection (ICRP) and the International Commission on Radiation Units and Measurements (ICRU). In addition, the international Standard Organization (ISO) provides guidance on calibration and uses of dosimeters and instruments in terms of these quantities. The International Atomic Energy Agency (IAEA) uses the recommendations and definitions of the ICRP, ICRU and ISO as a basis for its guidance in radiation protection. Quantities and units have been defined for describing the radiation beam (IAEA, 2005).

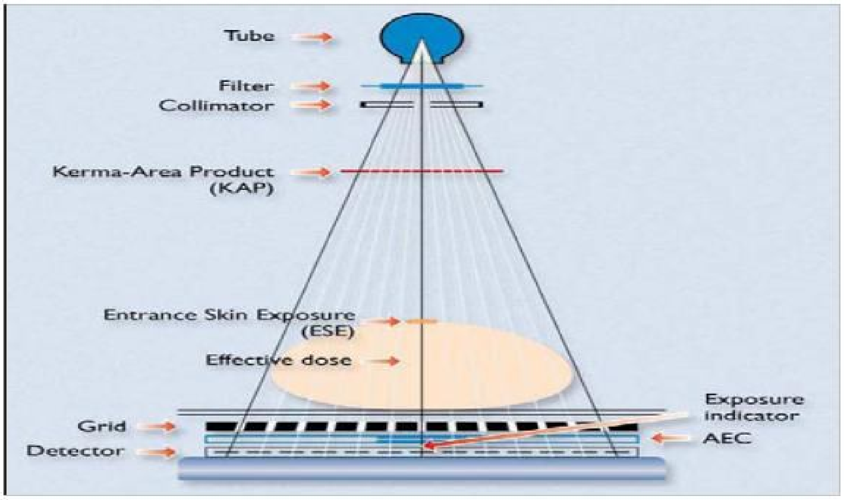


Figure 2.6: Typical examination beam geometry and related radiation dose quantities.

2.9.1. Exposure:

Exposure is a radiation quantity that expresses the concentration of radiation delivered to a specific point, such as the surface of the human body. There are two units for expressing Exposure. The conventional unit which is the Rontgen (R) and the SI unit which is the Coulomb/kg of air (C/kg of air). The unit Rontgen is officially defined in terms of the amount of ionization produced in a specific quantity of air. The ionization process produces an electrical charge that is expressed in the unit of Coulombs. Thereby, by measuring the amount of ionization in a known quantity of air the exposure in (R) can be determined (James E. Martin, 2006).

2.9.2. Air Kerma:

Air kerma is a radiation quantity that is used to express the radiation concentration delivered to a point, such as the entrance surface of a patient's body. It is a quantity that fits into the SI scheme. The quantity, kerma, originated from the acronym, KERMA, for Kinetic Energy Released per unit Mass (of air). 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, called gray (Gy) (James E, 2006).

2.9.3. Absorbed dose:

Absorbed Dose is the radiation quantity used to express the concentration of radiation energy actually absorbed in a specific tissue. This is the quantity that most directly related to the biological effects. Dose values can be expressed in traditional unit (rad) or in the SI unit of gray (Gy). The rad is equivalent to 100 ergs of energy absorbed in a gram of tissue and the gray is one joule of energy absorbed per kilogram of tissue (James E. Martin, 2006).

2.9.4. Entrance surface dose:

Entrance skin exposure is defined as the exposure in (R) at the skin surface of the patient excluding the backscatter contribution from the patient. This measurement is popular because entrance skin exposure is easy to measure, but unfortunately the entrance skin exposure is poorly suited for specifying the radiation received by patients undergoing radiographic examination. The entrance skin exposure does not take into account the radio sensitivity of individual organs or tissues, the area of an X-rays beam, or the beam's penetrating power, therefore, entrance skin exposure is poor indicator of the total energy imparted to the patient (James E. Martin, 2006).

2.9.5. Entrance surface air kerma (ESAK):

The entrance surface air kerma (ESAK) is defined as the kerma in air at the point where the central radiation beam axis enters the hypothetical object, i.e. patient or phantom, in the absence of the specified object. The entrance surface dose, or alternatively the entrance skin dose (ESD) is defined as the absorbed dose to air on the X-rays beam axis at the point where x-ray beam enters the patient or a phantom, including the contribution of the backscatter. The ESD is expressed in mGy. Some confusion exists in the literature with regard to the definition of the ESD. That is, whether the definition should refer to the absorbed dose to the air as defined above examination or absorbed dose to tissue (James E. Martin, 2006).

2.9.6. Collective effective dose:

The collective dose to the population is the sum over all types of examinations, of the mean effective dose, for specific examination type multiplying by the number of these examinations (n). The unit of collective effective dose is man Sv. The per capita effective dose is also used to quantify exposures that result from diagnostic radiology, it is the collective effective dose averaged over population of both exposed and non-exposed individuals (James E. Martin, 2006).

2.10. Radiation units:

2.10.1. Rontgen (R):

The Rontgen is a unit used to measure a quantity called exposure. This can only be used to describe an amount of gamma and X-rays, and only in air. Where (1R) is equal to depositing in dry air enough energy to cause 2.58×10^{4} Coulombs per Kg. It is a measure of the ionizations of the molecules in a mass of air. The main advantage of this unit is that it is easy to measure directly, but it is limited because it is only for deposition energy in air, and only for gamma and X-rays (Jaypee et al, 2001).

2.10.2. Radiation absorbed dose (Rad):

The Rad is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material, and is used for any type of radiation and any material. The Rad is defined as the absorption of 100 ergs per gram of material. The unit Rad can be used for any type of radiation, but it does not describe the biological effects of the different radiations (Jaypee et al, 2001).

2.10.3. Rem (Rontgen equivalent man):

The rem is a unit used to measure a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Taking into account that not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms milirems. To determine equivalent dose (rem), we multiply the absorbed dose (rad) by a quality factor (Q), which is unique for the type of incident radiation (Jaypee et al, 2001).

2.10.4. Gray (Gy):

The gray is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in a material, and is used for any type of radiation and any material. Where one gray is equal to one joule of energy deposited in one Kg of a material. The unit gray can be used for any type of radiation, but it does not describe the biological effects of the different radiations. Absorbed dose is often expressed in terms of centigrays. One gray is equivalent to 100 rad (Jaypee et al, 2001).

2.10.5. Sievert (Sv):

The Sievert is a unit used to measure a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of microsievert. To determine equivalent dose (Sv), we multiply absorbed dose (Gy) by a quality factor (Q) which is unique for the type of incident radiation. One sievert is equivalent to100 rem (Jaypee et al, 2001).

2.11. Calculation of ESD from Exposure Factors:

ESD may be calculated in practice by knowing the tube output, the relationship between the X-rays unit current-time product (mAs) and the air kerma in air which is established at a reference point in the X-rays field at 80 KV_p tube potential. Subsequent the estimate of the ESD can be done by recording the relevant parameters (tube potential, filtration, mAs and FSD) and correcting for distances and back scattered radiation as shown in equation below:

$$ESD = OPx\left(\frac{kV}{80}\right)^2 xmAsx\left(\frac{100}{FSD}\right)^2 BSF$$

Where OP is the tube output per mAs measured at a distance of 100 cm from the tube focus along the beam axis at 80 KV_p. KV is the peak of the tube voltage. (kVp) recorded for any given examination. Where in many cases the output is measured at 80 KV_p, and therefore this appears in the equation as a quotient to convert the output into an estimate of that which would be expected at the operational KV_p. The value of 80 KV_p should be substituted with whatever KV_p the actual output is recorded at in any given instance. mAs are the tube current-time product which is used in any given instant, FSD is the focus-to-patient entrance surface distance and BSF is the Backscatter factor (Jaypee et al, 2001).

2.12. Previous studies:

Through the last two decades, several surveys have been performed studying the annual collective effective doses in different countries. The lessons learned from these studies are first of all the recognition of the significant variations in patient doses between different radiological departments for the same type of examinations.

A. Aroua (2007) conducted a nationwide investigation in Switzerland to establish the exposure of population by medical X-rays and update the result of 1998 survey; the frequency study addressed 206 general practitioners, 30 hospitals and 10 private radiology institutes.

The investigation showed that the total number of all medical X-rays examination performed by GPs registered a 1% decreased between 1998 and 2003. The study indicated also that the total number of all x-ray examinations performed in hospitals increased by 4% with a slight increase of radiographies by 1%, both changes in the frequency and the effective dose led to 20% increase in the collective dose. The author recommended that two types of updating are necessary; an updating survey every 5 years and a re-evaluation survey every 20 years.

Ioana Sorop (2008) performed national study in Romania to update the magnitude of medical radiation exposure from conventional X-rays examinations, in order to optimize the radiological protection to the population in a cost-effective manner. Effective doses from diagnostic radiology were estimated for adult and pediatric patients undergoing the most important types of X-rays examination. Data were collected from 179 X-rays departments, selected by their annual workload, throughout the country. Estimates were made using two dosimetric quantities; entrance surface dose (ESD), derived from the absorbed dose in air measured by simulation of radiographic examinations, and dose-area product, measured during fluoroscopic examinations performed on adult and pediatric patients. Conversion coefficients to effective dose of the UK National Radiological Protection Board (NRPB) have been used in all calculations. So he found that the effective dose per patient from all medical X-rays examinations was 0.74 mSv and the resulting annual collective effective dose was 6930 man Sv, with annual effective dose per capita of 0.33 mSv. The current size of population exposure from diagnostic radiology is lower than the previous one by 40 percent.

Osman 2010, measured patient dose in routine X-rays examinations in Omdurman teaching hospital Sudan. A total of 110 patients were examined and 134 radiographs were obtained in two X-rays rooms. Entrance surface doses (ESDs) were calculated from patient exposure parameters using DosCal software. The mean ESD for the chest, lateral lumbo-sacral spine, anterior posterior lumbar spine, were, (231 44) mGy, (716 9) mGy, (611 55) mGy, respectively. Also he has compared his results with previous studies in Sudan and Brazil. Osman, found that the ESD for chest radiographs are comparable to those reported in previous studies Performed by Olivera Ciraj et al. and Henner Anja respectively. And for lumbo-sacral spine AP and lateral it is also reduced by factor of 59%, 90%, 132%, 93% for study of Olivera Ciraj et al. and Kepler .K et al. respectively.

Cornelia Diaconescu and Olga Iacob (2002) update the annual frequency of X-ray examinations and the pattern of pediatric radiology in 2000. Also, to assess in terms of effective dose the magnitude of pediatric patient exposure during conventional X-rays examinations, selected by their high frequencies or their relatively high doses delivered to patient. The annual effective doses from all medical examinations for the average pediatric patients were as follows: 0.85 mSv for 0 year old, 0.53 mSv for 1 year old, 0.56 mSv for 5 year old, 0.72 mSv for 10 year old and 0.74 mSv for 15 year old. The resulting annual collective effective dose was evaluated at 872 man-Sv, with the largest contribution of pelvis and hip examinations.

In order to determine current levels and recent nationwide trends in radiological examination frequency, as well as to update corresponding collective effective dose estimates. Examination frequencies were obtained from radiology management systems at all hospitals and private radiology enterprises across Norway in terms of number of examination codes. During the last decade, the overall examination frequency increased by 16% to 910 per 1000 inhabitants, excluding nuclear imaging and dental radiology. The largest increase in examination frequency occurred in MRI (10-fold increase) Total patient collective effective dose from diagnostic radiological examinations, CED, in units of man Sv, was calculated according to the formula, CED = EiNi, where Ei is the mean effective dose to patients from a particular examination type and Ni is the corresponding number of examinations of that type performed each year.

The contribution to collective Effective dose from radiological examinations was estimated to 4960 man Sv or 1.09 mSv per inhabitant; representing a 40% increase from 1993 to 2002. Estimates of the mean effective dose for each examination type were predominantly obtained from national dose surveys carried out by NRPB and published by Olerud and his colleagues. Organ-weighting factors according to ICRP Publication 60 were used in these dose surveys, this study conducted by Ingelin BA rretzen (2007).

To estimate the annual UK per capita effective dose from all medical and dental X-rays examinations, information is required on the annual frequency and the mean effective dose for each type of examination. A recent NRPB survey of the frequency of X-rays examinations in the UK in 1997/98 has been used to provide the information on the annual numbers of X-rays examinations. Estimates of the mean effective dose for each examination were obtained from a number of sources, the predominant one being the National Patient Dose Database maintained by NRPB. This contains data collected in the period from 1988 to 2000 covering about 60 types of radiograph and 100 types of X-rays examination. For other types of examination and when the information held on the national Patient Dose Database was found to be inadequate to derive reliable effective doses. The objective of the past reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (U3, U4, U6, U7, U9, and U10) with respect to medical exposures has been to establish the annual frequency of medical examinations and procedures involving the use of radiation as well as their associated doses. Reviews have been performed of practice in diagnostic radiology; Data have been analyzed to deduce temporal trends, to evaluate the collective population dose due to medical exposure and to identify procedures for which the doses are major contributors to the total collective dose.

In earlier UNSCEAR reports on doses from medical irradiation (U10, U11) the annual frequency of medical exposures was estimated on the basis of a very limited series of surveys, mainly not exclusively performed in developed countries, initially information was obtained under board headings such as diagnostic radiography or diagnostic fluoroscopy [3],The UNSCEAR 1982 report (U9) was the first to use a surveys, developed by WHO in cooperation with UNSCEAR to obtain information on the availability of diagnostic radiology equipment and the annual frequency of diagnostic x-ray examination in various countries.

In the 1977 report U7 there was a brief review of the frequency of diagnostic x-ray examination in various countries, surveys made in Japan up to 1974, in Sweden up to 1974 and in United States in 1964 and 1967 where analyzed in terms of frequency of diagnostic x-ray examinations by type. Since the new surveys have become available from Australia, Finland, Federal Republic of Germany, Japan, Poland, Romania, Sweden, the USSR and the United Kingdom, the data available have been expressed in terms of the annual per capita examination in order to allow comparison between countries to be made.

The total collective effective dose from diagnostic x-ray examination in Poland in 1976 was reported to be 20,000 man Sv which corresponds to about 600 man Sv per million populations, the total collective effective dose from diagnostic x-ray examination in Japan in 1974 was estimated to be 200,000 man Sv which corresponds to be 1800 man Sv per million population. The committee had no other quantitative information from which to obtain reasonable estimate of collective effective dose applying generally to population of the world. The data from Poland and Japan differ by a factor of about 3. On the assumption that these data might be applicable to other areas, the annual collective effective attributable to medical irradiation for diagnostic purposes might be of the order of 1000 man Sv per million population in industrialized countries this is an annual per caput effective dose to 1 mSv.

In developing countries, having lower frequency of examinations the value would be correspondingly less. The purpose of UNSCEAR 2008 report is to assess the magnitude of use of medical exposures around the globe in the period 1997-2007, to determine the relative contribution to doses from various modalities and procedures and to assess trends [12], In the period 1997-2007 covered by the 2008 UNSCEAR report, the estimated annual collective effective dose to the world population from diagnostic medical and dental radiological examination is estimated to be 4000,000 man Sv, Since the previous survey (U3) there has been arise of approximately, 1,700,000 man Sv. This increase results in part from an increase in the annual frequency of diagnostic medical.

Atalabi Omolola M., Akinlade Bidemi I., Adekanmi Ademola J. and Samuel Olutayo A showed that children below the age of 1 year received minimum and maximum ESD of (10.29 3.80) Gy and 105.56 Gy respectively, from all X-rays examinations. The minimum and the maximum effective dose received from head and neck examination by the same age group was (10.59 4.61) Sv and (105.560.00) Sv respectively. The children in the age group (1-5) years received the lowest mean ESD of (10.06 3.23) Gy in the upper limbs and highest mean ESD of (128.18 73.61) Gy in the Head and neck examinations. For age groups (5-10) years and (10-15) years, the minimum ESD received for all examinations was (56.36 32.11 500) Gy, while the maximum ranges from mean value was (880.04 89.44) Gy. The highest ESD for age group (5-10) years was from pelvic examinations while age group (10-15) years received highest ESD was from head and neck examinations. The effective dose values of age groups (1-5) years, (5-10) years and (10-15) years were highest in the chest examinations with a mean of (50.20 44.81) Sv, (65.17 22.32) Sv and (66.74 30.84) Sv respectively.

Chapter Three

MATERIALS AND METHODS

3.1. Materials:

This study was carried out in two hospitals in Khartoum state; included two X-rays machines. The hospitals namely, are: Khartoum hospital (KH) and Omdurman hospital (OH). Initially, questionnaires were distributed to radiographers in charge of the diagnostic facilities. Each radiographer was asked to provide information with respect to his X-rays radiography unit, including manufacturer, model, screen type and film speed. To calculate the ESD, the radiographer was asked also to provide the typical exposure parameters used for five groups of patients aged as; newborn, 1, 5, 10 and 15 years. The parameters were: peak tube voltage (kVp), exposure current-time product (mAs), focus-to-film distance (FFD), the dose values were obtained with the use of the DosCal software that provides the ESD as well as the ED. The use of software packages to perform patient doses is a modern resource in dosimetry and is being widely used in hospitals. The calculation of ESD from output measurements and exposure factors is a realistic alternative method to (Thermolummesent dosimetry) TLD measurement. The software used in this work was a computer-based system by which patient doses can be determined from exposure factors recorded at the time of the examination. For the DosCal software, the tube output of all X-rays machines was measured using calibrated ionization chamber recheck plus X-rays exposure meter. In the present study, two different modalities X-rays machines from different manufacture were used as described in Table 3.1. Hospitals that participated in the study included public hospitals; these hospitals were chosen for this study because they are the largest hospitals in the country in terms of workload.

Table 3.1 Type and main characteristics of X- ray machine.

Center	Manufacturer	Manufacturing Date	Type	Focal spot (mm)	Total Filtration (mm Al)	Max KVp	Max mA	Year install
KH	Shimazdu	Dec 2011	fixed	1.2	1mm	150	500	2013
OH	Shimazdu	2010	Fixed	1.2	1mm	150	500	2012

3.1.1. Patient samples:

A total of 50 patients were examined in two hospitals in Khartoum state. The data were collected using a sheet for every patient in order to maintain consistency of the information. The following parameters age, weight, height, tube voltage, and tube current-time product setting exposure parameters were recorded.

3.2. Methods:

3.2.1. Imaging technique:

In routine X-rays examinations for pediatric chest X-rays, the frontal view anterior posterior (AP) mainly used. For chest X-rays it is preferred that the patient stand for this exam, particularly when studying collection of fluid in the lungs and during the actual time of exposure, the technologist usually asks the patient to hold his or her breath. This is very important in chest X-rays to ensure there is no motion that could detract from the quality and sharpness of the lm image.

3.2.2. Patient preparation:

There is no advance preparation necessary for routine X-rays. A hospital gown is used to replace all clothing on the upper body and all jewellery must be removed from the examined organ. All examinations were performed according to the technique used in each hospital.

3.2.3. Absorbed Dose calculations:

ESD which is defined as the absorbed dose to air at the centre of the beam including backscattered radiation, measured for all patients using mathematical equation in addition to output factor and patient exposure factors. The exposure to the skin of the patient during standard radiographic examination or fluoroscopy can be measured directly or estimated by a calculation to exposure factors used and the equipment specifications as in equation below.

$$ESD = OPx\left(\frac{kV}{80}\right)^2 xmAsx\left(\frac{100}{FSD}\right)^2 BSF$$

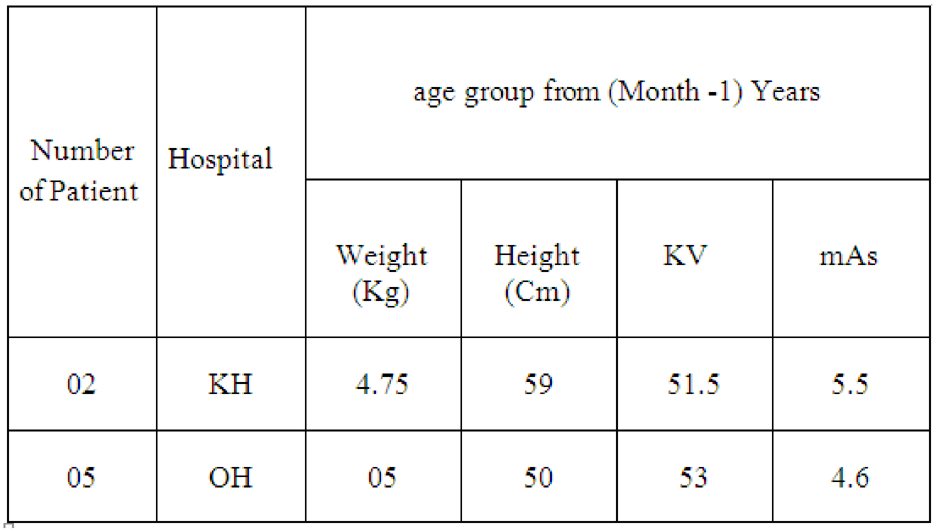
Where (OP) is the output in mGy per (mA s) of the X-rays tube at 80 KV at a focus distance of 1 m normalized to 10 mAs. (KV) the tube potential. (mAs) the product of the tube current (mA) and the exposure time (s). (FSD) the focus-to-skin distance (cm). (BSF) the backscatter factor. The normalization at 80 kV and 10 mAs was used as the potentials across the X-rays tube and the tube current are highly stabilized at this point. BSF is calculated automatically by the Dose Cal software after all input data are entered manually in the software. The tube output, the patient anthropometrical data and the radiographic parameters (kVp, mAs, FSD and filtration) are initially inserted in the software. The kinds of examination and projection are selected afterwards.

Chapter Four

RESULTS

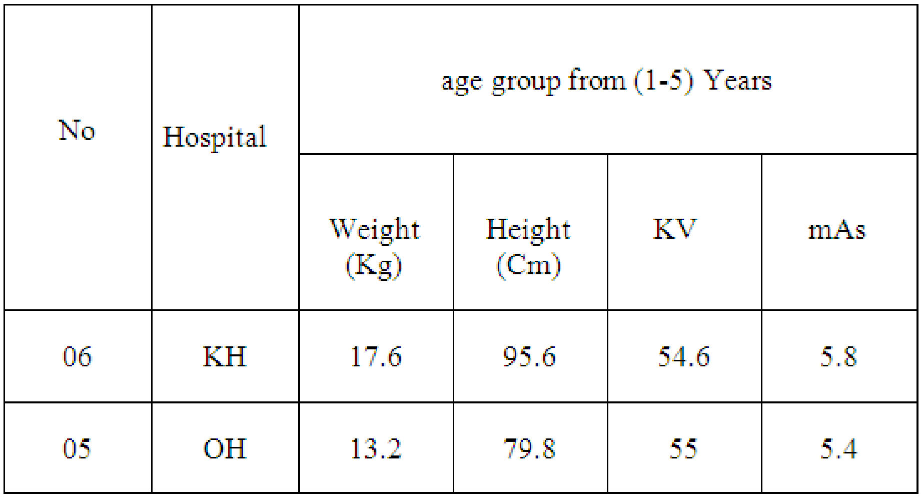
The tables below show the mean value of weight, height, KV, mAs, for specific age group in each hospital.

Table (4.1) show the mean value of weight, height, KV, mAs, for pediatric patients for age group from (Month -1) Years.



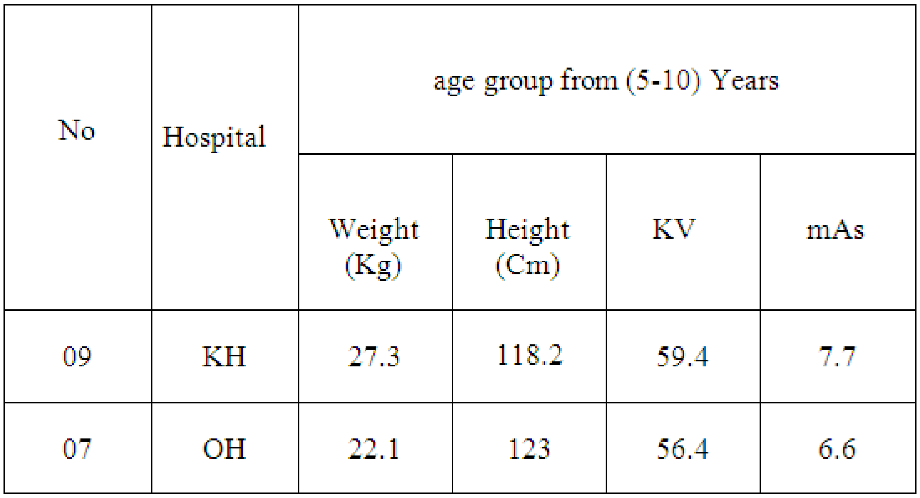
Number of Patient	Hospital	age group from (Month -1) Years			
		Weight (Kg)	Height (Cm)	KV	mAs
02	KH	4.75	59	51.5	5.5
05	OH	05	50	53	4.6

Table (4.2) show the mean value of weight, height, KV, mAs, for pediatric patients for age group from (1 -5) Years.



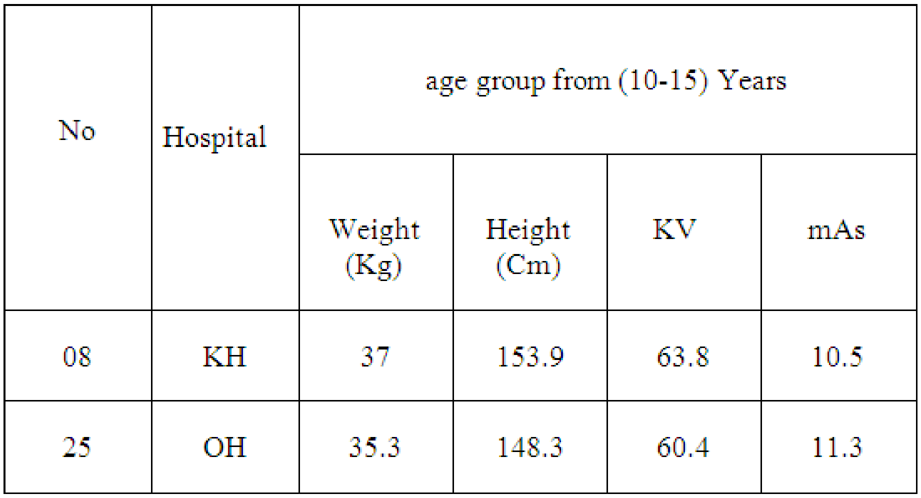
No	Hospital	age group from (1-5) Years			
		Weight (Kg)	Height (Cm)	KV	mAs
06	KH	17.6	95.6	54.6	5.8
05	OH	13.2	79.8	55	5.4

Table (4.3) show the mean value of weight, height, KV, mAs, for pediatric patients for age group from (5 -10) Years.



No	Hospital	age group from (5-10) Years			
		Weight (Kg)	Height (Cm)	KV	mAs
09	KH	27.3	118.2	59.4	7.7
07	OH	22.1	123	56.4	6.6

Table (4.4) show the mean value of weight, height, KV, mAs, for pediatric patients for age group from (10 -15) Years.



No	Hospital	age group from (10-15) Years			
		Weight (Kg)	Height (Cm)	KV	mAs
08	KH	37	153.9	63.8	10.5
25	OH	35.3	148.3	60.4	11.3

Table (4.5) shows the mean values of ESD and ED obtained in this study for study samples.

ESD (*m*Gy)	Khartoum Hospital	Omdurman Hospital
Mean	.0542	.0487
SD	.04152	.04886
Min	.022	.015
Max	.17	.223
Variance	.00172	.00239
BMI	17.76	18.1
ED (µSv)	0.0082	0.0043

Table (4.6) shows the organ equivalent doses values in mSv calculated in this study.

Hospital	KH	OH
ESD	.0542	.0487
Lung	0.022	0.0121
Breast	0.038	0.0224
Thyroid	0.026	0.0149
Liver	0.014	0.008
Kidney	0.001	0.001
Bladder	0.006	0.0035
Stomach	0.0131	0.006
Testis	0.00002	0.00007

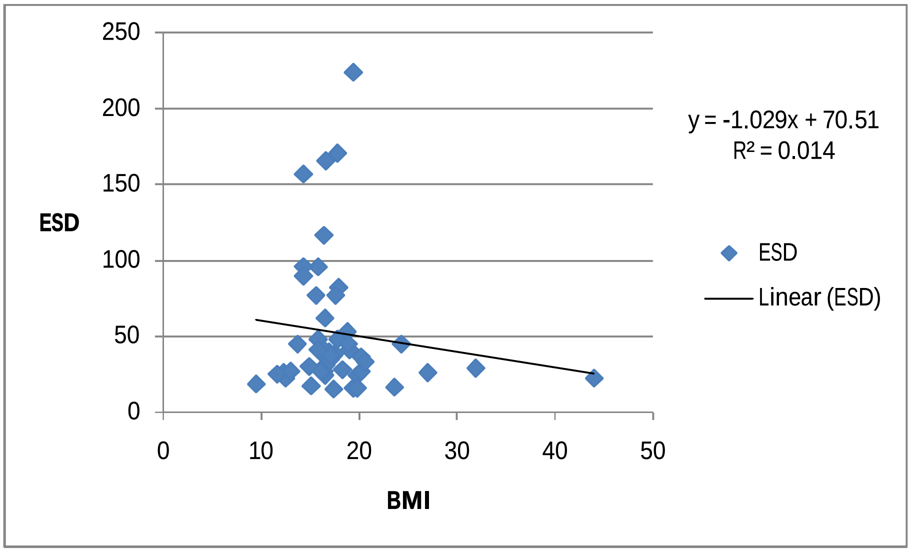


Figure 4-1. Correlation between entrance skin dose ESD (MGy) and body mass index BMI (Kg/m2) of patients undergoing Chest X-ray for study sample.

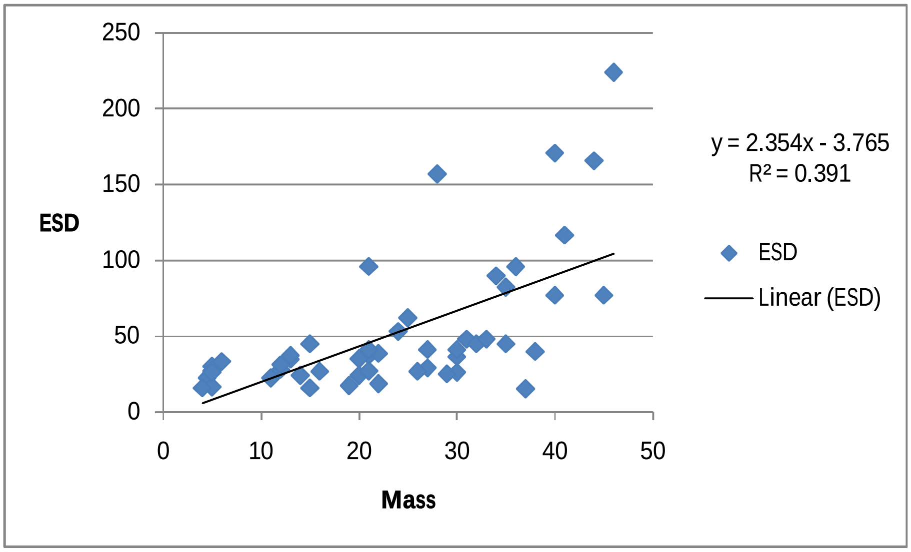


Figure 4-2: correlation between entrance skin dose ESD (MGy) and weight (mass) of the body (Kg) of patients undergoing chest X-ray for study sample.

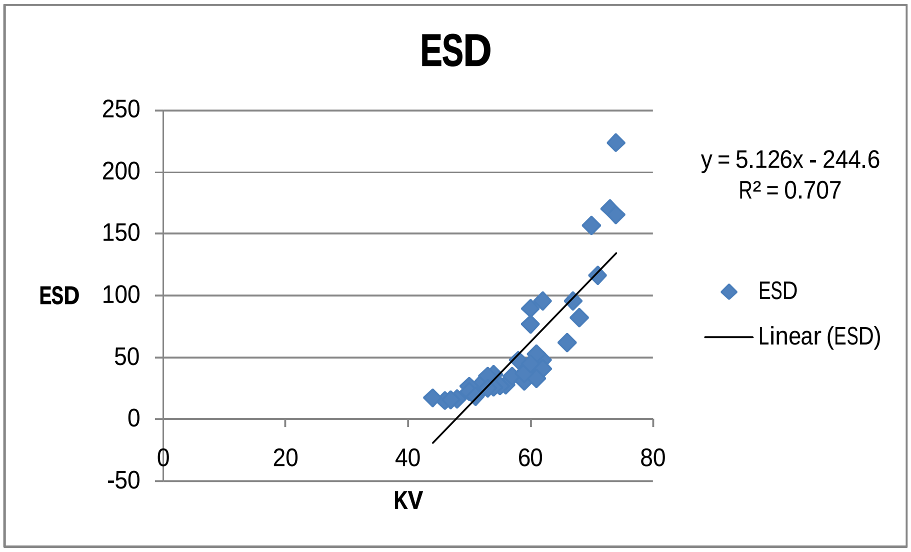


Figure 4-3: correlation between entrance skin dose ESD (MGy) and tube potential kVp to patients undergoing chest X-ray for study sample.

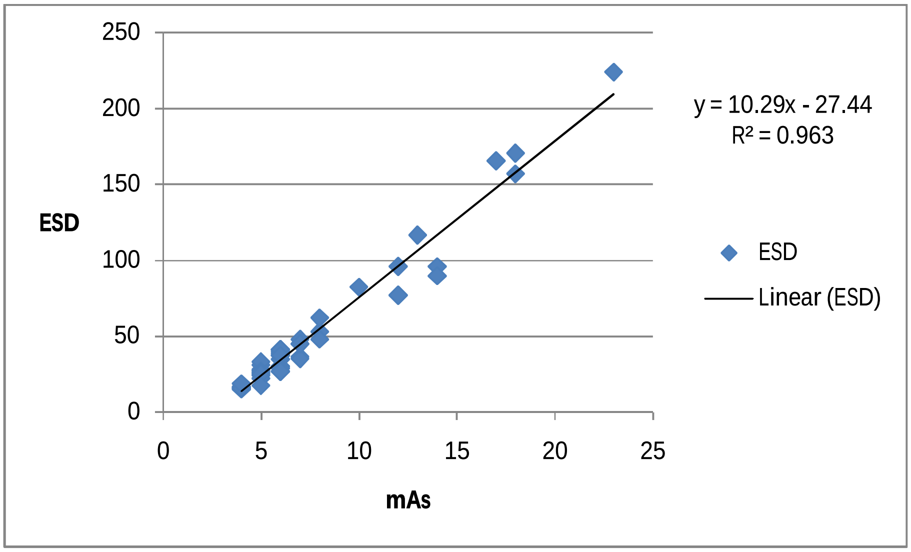


Figure 4-4: correlation between entrance skin dose ESD (MGy) and time current product to patients undergoing chest X-ray for study sample.

Chapter Five

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1. Discussion:

Fig. 4.1 and Fig. 4.2. Show that there is no correlation found between the ESDs values, the weight and the BMI in both hospitals. The reason for this lack of correlation between ESD and patient weight, BMI is the subjective manual selection of the tube voltage values and other exposure parameters for most of the patients. The mean ESDs per chest radiographic image are (.0542) mGy and (.0487) mGy in (KH) and (OH) respectively. These values are slightly lower than the corresponding values reported in the DRLs report in the European guidelines on quality criteria for diagnostic radiographic images EUR 16260EN. The mean ED per chest radiographic image (.0082) mGy and (.0043) mGy in (KH) and (OH) respectively. Generally, there are no significant different in the values of ESDs recorded in this survey and other previous studies. However, lower ESDs were recorded for the chest examinations in this study was lower than which recorded in the previous studies. Obtaining difference values of ESDs is attributed to the use of low kilovolts. The difference also could be due to imaging Protocols and the state of some of the equipment used in the two hospitals in concern.

5.2. Conclusion:

The patient dose was measured in two hospitals in different computed radiography modalities, the radiation dose was found higher in Khartoum Hospital than in Omdurman Hospital. The results of the present study showed that optimization of technical and clinical factors may lead to a substantial patient dose reduction. The results of this study allow a better understanding of how different working habits and examination techniques influence the patient dose and make medical staff aware of their responsibility for optimization of daily radiological practice. Different in the values of ESDs recorded in this study is due to the manual selection of exposure factors and also due to imaging technique in OH the imaging technique is computed radiography, in KH the imaging technique is film screen which required higher exposure factors than computed radiography.

5.3. Recommendations:

X-rays Radiography operator should be optimized; this is by using the best strategies available for reducing radiation dose. High level training for X-rays Radiography staff is highly recommended. Each radiology department should implement a patient dose measurement quality assurance program. Practical guidelines for better image quality in X-rays radiography is mainly concerned with the professional skills of the users and the establishment of an efficient quality control program specifically designed to produce the best quality of clinical images. Radiologists should support and encourage staff within the radiology department to appreciate the importance of an effective quality control program. In addition, radiographers who utilize the technology should also receive proper training on developing professional skills. A successful digital radiology enterprise will undoubtedly earn immeasurable benefits from an effective quality control program and skilful radiographers who correctly utilize the technology. Reference dose levels for diagnostic radiology should be established on the national scale, in order to reduce the patient exposure and to maintain a good diagnostic imaging. Filtration and collimation of the X-rays beam are very important in diagnostic radiology; safety measures keep doses As Low as Reasonably Achievable (ALARA) principle in diagnostic radiology to reduce the radiation dose for patients. Short exposure times can improve image quality and reduce the number of films repeated. More studies should be carried out especially in hospitals using old diagnostic facilities.

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