Chapter one: Introduction

1.1 Introduction:

Chest X-ray examination is one of the most frequently required diagnostic procedure used in clinical practice and it may also be implemented in screening programs for large populations, with a significant impact on the collective dose. According to ICRU report 70 the chest radiography is responsible for approximately 25% of all X-ray examination performed. Since the use of digital techniques in radiographic imaging are rapidly growing, it is important to assess and review the exposure settings, for example the tube voltage, used to obtain the Images. Digital technology has not only the potential to reduce patient doses, but also the risk to increase the number of exposures and the dose required to obtain images of enough quality. Experience has shown that many radiology departments have made the transition to digital equipment; patient doses have been measurably increased Diagnostic X-rays are used extensively in medicine that they represent by far the largest Man-made source of public exposure to ionizing radiation. Each year, Thousands of diagnostic x-ray procedures are performed in Sudan. Although radiation exposure connected with these procedures cannot be avoided, there are means to reduce it as much as possible. Patient Radiation dose from conventional radiographic procedures ranges from 0.1 mSv to 10 mSv, resulting in a collective dose to the population that can be significant. Today, Quality and safety have become hallmarks for efficient and successful of any medical procedure. The establishment of the Quality Criteria for Diagnostic Radiology Images started in 1984 when the first Directive on Radiation Protection of the Patient was adopted by the Member States of the European Union. During recent years, patient dose has become a major issue and because of the increasing awareness and greater realization of the effects of ionizing radiation, X-ray users are now more demanding of dose information and dose reduction. Recently quality and safety

culture has been progressively developed in Sudan with regard to the medical use of ionizing radiation for diagnosis and treatment. The two basic principles of radiation protection of patient recommended by the ICRP are justification of practice and optimization of protection. In diagnostic radiology, periodic dose assessments should be made to encourage the optimization of the radiation protection of the patients. Dose measurements are required further to compare different radiological techniques and to comply with some international guidelines and regulations. During the last ten years many studies are conducted on the radiation dose due to clinical x-ray examinations. These studies in addition to many international researches have reported wide variations in patient dose arising from specific X-ray examinations.Reasons for these dose variations were complex but, in general, low tube potential, high mAs and low filtration were associated with high-dose hospitals.The main task of this study is evaluating the radiation doses to patients undergoing Chest X-ray examinations in two major hospitals in Khartoum State and to compare those estimated dose level with the established reference dose levels (Paydar et al, 2012).

1.2 Radiation dose and it related risk:

It is important to evaluate relative and absolute risk, and the concept of justification. Justification is even more important when one is considering a research study involving ionizing radiation or a screening program. The effective dose provides a limited method to estimate the stochastic risk, but the uncertainties in this estimate must be appreciated and communicated. The limitations of the effective dose for use in diagnostic radiology patient doses must be understood, including the variability of risk with age, dose rate, etc. Other important topics include cancer risk estimation from applying BEIR V risk data to organ doses that are usually known through Monte Carlo techniques, variations in risk based on radiography projection (eg.PA vs. AP

projection), typical doses and risks from medical exposures and the contribution of population collective dose from medical exposures. Deterministic effects, though limited in diagnostic radiology, are important since they can produce significant morbidity in patients undergoing interventional procedures and, in limited number of cases, diagnostic procedures.

1.3. Organ dose evaluation:

Organ doses will be evaluated from skin entrance exposure by means of the Monte Carlo program developed by National NRPB (NRPB-262), which also requires the following input data: type of examination, KVp, source to image receptor distance, HVL, beam sizes. For a standard patient, the Monte Carlo program gives the doses to the following organs: gonads, spleen, bone marrow, breast, lung, eye lens and thyroid. During the fluoroscopic procedure the TLDs will be kept in the required position and are fixed in place with cello-tapes. Also organ dose will be estimated by using NRPB software for organ dose estimation.

1.4. Problem of Study:

The problem is caused from incorrect use of radiography equipment and from the radiation exposure to patients may be much more than required in radiology department in Alshab Teaching Hospital and Omdurman Teaching Hospital .International Commission on Radiation Protection (ICRP), the International Atomic Energy Agency (IAEA) have been making publications in ionizing radiation protection , Report 60 of the ICRP and the Basic Safety Standards that was published in the IAEA report have three basic principles related to the radiation protection (ICRP, 1991; IAEA, 1996).Exposure of different dose values for the same clinical examination is an enough reason to draw attention to this issue.

1.5. Objectives of the study:

The main objective of this study is to Evaluate Patient Radiation Dose during Conventional Chest X-Ray in Khartoum.

1.5.1. Specific Objectives:

- To estimate and calculate Entrance Surface Dose (ESD) and Effective Dose (ED) for patients undergo conventional chest x-rays in Khartoum.
- To estimate the radiation risks according to measured dose.
- To find the correlation between entrance surface dose and weight , Kvp , mAs , body mass index.

1.6. Overview of the Study:

This thesis is concerned with the evaluation of patient radiation dose in chest X-ray using monte carlo calculations radiography.This study falls into five chapters, Chapter one, which is an introduction, It presents the statement of the study problems, objectives of the study, chapter two, contains the background material for the thesis. Specifically it discusses the dose for all absorbed dose measurements and calculations. This chapter also includes a summary of previous work performed in this field and reviewed different dosimetric techniques used in patient dose measurements. Chapter three describes the materials and a method used to measure dose for routine radiography machines and explains in details the methods used for dose calculation, Chapter fours deals with results and discussions. Chapter five conclusion , recommendations and references.

Chapter two

Literature Review

2.1. Ionizing Radiation:

Ionizing (high-energy) radiation has the ability to remove electrons from atoms; i.e., to ionize the atoms. Ionizing radiation can be electromagnetic or particulate radiation (Fig. 2.1). Clinical diagnostic radiation uses photons (electromagnetic) as radiation in the diagnosis of disease and some benign conditions (Murat et al, 2010).

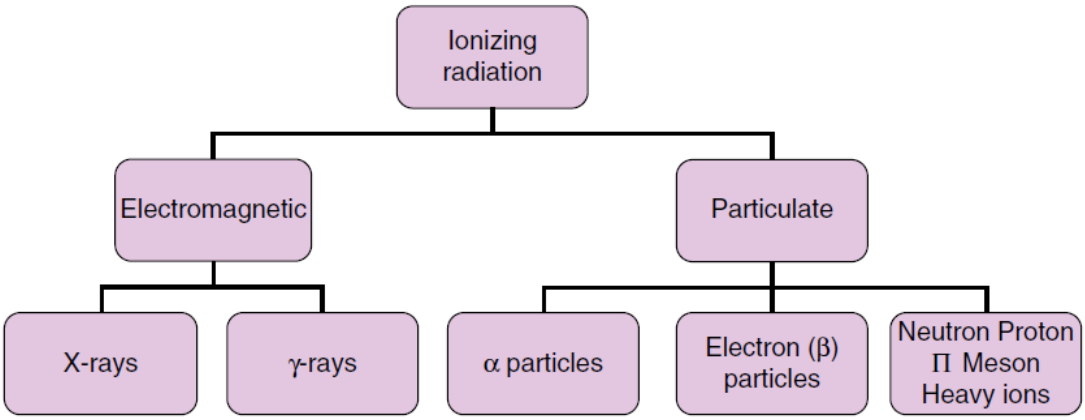


Figure (2.1) show the types of Ionizing radiation(Murat et al, 2010).

2.2 Production of X-Rays:

X-rays were discovered by Roentgen in 1895 when high-speed electrons are decelerated on collision with high atomic number material while studying cathode rays (stream of electrons) in a gas discharge tube. He observed that another type of radiation was produced (presumably by the interaction of electrons with the glass walls of the tube) that could be detected outside the tube. This radiation could penetrate opaque substances, produce fluorescence, blacken a photographic plate, and ionize a gas. He named the new radiation x-rays (ICRP, 2001).

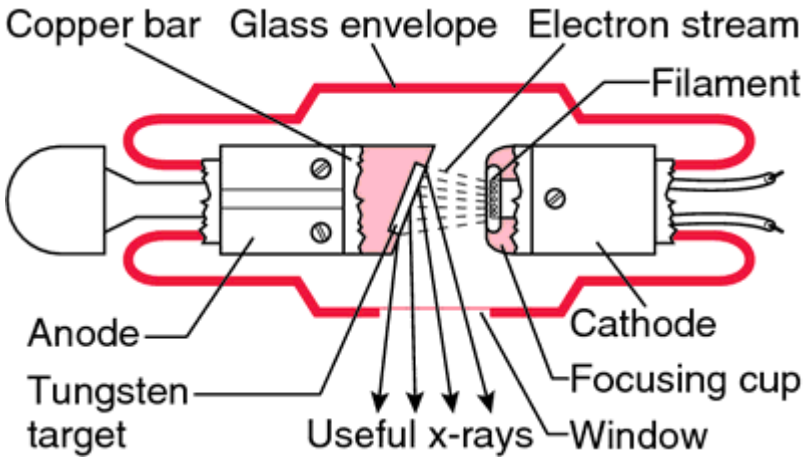


Figure (2.2) show the diagram of X-ray tube component

http://medical-dictionary.thefreedictionary.com/x-rays

2.2.1 Bremsstralung X-rays:

The process of bremsstrahlung is the result of radiative interaction between a high-speed electron and a nucleus. The electron while passing near a nucleus may be deflected from in path by the action of Coulombforces of attraction and loses energy as bremsstrahlung, a phenomenon predicted by Maxwell's general theory of electromagnetic radiation. According to this theory, energy is propagated through space by electromagnetic fields. As the electron, with its associated electromagnetic field, passes in the vicinity of a nucleus; it suffers a sudden deflection and acceleration. As a result, a part or all of its energy is dissociated from it and propagates in space as electromagnetic radiation. Since an electron may have one or more bremsstrahlung interactions in the material and an interaction may result in partial or complete loss of electron energy, the resulting bremsstrahlung photon may have any energy up to the initial energy of the electron. Also, the direction of emission of bremsstrahlung photons depends on the energy of the incident electrons. At electron energies below about 100 KeV, X-rays are emitted more or less equally in all directions (Bushberg JT et al , 2002).

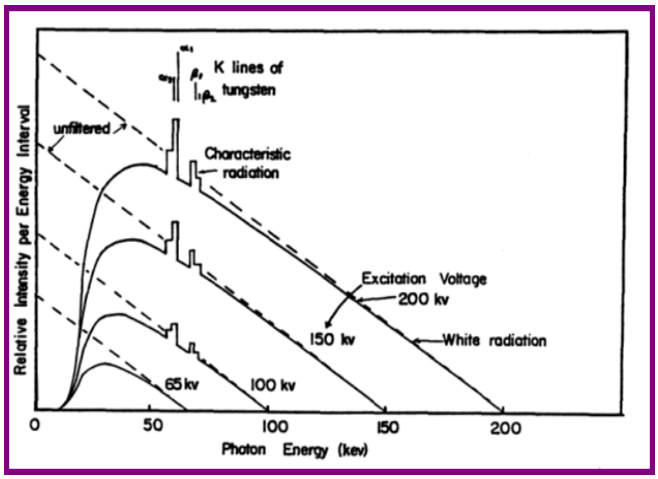
2.2.2 Characteristics X-rays:

Electrons incident on the target also produce characteristic X-rays. An electron with kinetic energy E_0, may interact with the atoms of the target by ejecting an orbital electron, such as a K, L, or M electron, leaving the atom ionized.The original electron will recede from the collision with energy when a vacancy is created in an orbit, an outer orbital electron will fall down to fill that vacancy. In doing so, the energy is radiated in the form of electromagnetic radiation. This is called characteristic radiation, i.e., characteristic of the atoms in the target and of the shells between which the transitions took place. With higher atomic number targets and the transitions involving inner shells such as K, L, M, and N, the characteristic radiations emitted are of high enough energies to be considered in the X-ray part of the electromagnetic spectrum (Bushberg JT et al , 2002).

2.2.3 Spectrum of X-ray:

X-ray photons produced by an X-ray machine are heterogeneous in energy. The energy spectrum shows a continuous distribution of energies for the bremsstrahlung photons superimposed by characteristic radiation of discrete energies. A typical spectral distribution is shown in Fig. The inherent filtration in conventional X-ray tubes is usually equivalent to about 0.5- to 1.0-mm aluminum. Added filtration, placed externally to the tube, further modifies the spectrum. It should be noted that the filtration affects primarily the initial low-energy part of the spectrum and does not affect significantly the high energy photon distribution. The purpose of the added filtration is to enrich the beam with higher-energy photons by absorbing the lower energy components of the spectrum. As the filtration is increased, the transmitted beam hardens, i.e., it achieves higher average energy and therefore greater penetrating power. Thus the addition of filtration is one way of improving the penetrating power

of the beam. The other method, of course, is by increasing the voltage across the tube. Since the total intensity of the beam (area under the curves in Fig. 2.3**)** decreases with increasing filtration and increases with voltage, a proper combination of voltage and filtration is required to achieve desired hardening of the beam as well as acceptable intensity. The shape of the X-ray energy spectrum is the result of the alternating voltage applied to the tube, multiple bremsstrahlung interactions within the target and filtration in the beam. However, even if the X-ray tube were to be energized with a constant potential, the X-ray beam would still be heterogeneous in energy because of the multiple bremsstrahlung processes that result in different energy photons. Because of the X-ray beam having a spectral distribution of energies, which depends on voltage as well as filtration, it is difficult to characterize the beam quality in terms of energy, penetrating power, or degree of beam hardening. A rule of thumb is often used which states that the average X-ray energy is approximately one-third of the maximum energy or KVp.Of course, the one-third rule is a rough approximation since filtration significantly alters the average energy. Another quantity, known as half-value layer, has been defined to describe the quality of an X-ray beam(Bushberg JT et al , 2002).



The figure(2.3) show the Spectral distributions of X-rays(Bushberg JT et al , 2002)

2.3 Interactions of Ionizing Radiation :

When an x- ray beam passes through a medium, interaction between photons and matter can take place with the result that energy is transferred to the medium. The initial step in the energy transfer involves the ejection of electrons from the atoms of the absorbing medium. These high-speed electrons transfer their energy by producing ionization and excitation of the atoms along their paths. If the absorbing medium consists of body tissues, sufficient energy may be deposited within the cells, destroying their reproductive capacity. However, most of the absorbed energy is converted into heat, producing no biologic effect(Bushberg et al.,2002).

2.3.1 Interaction of photon with matter:

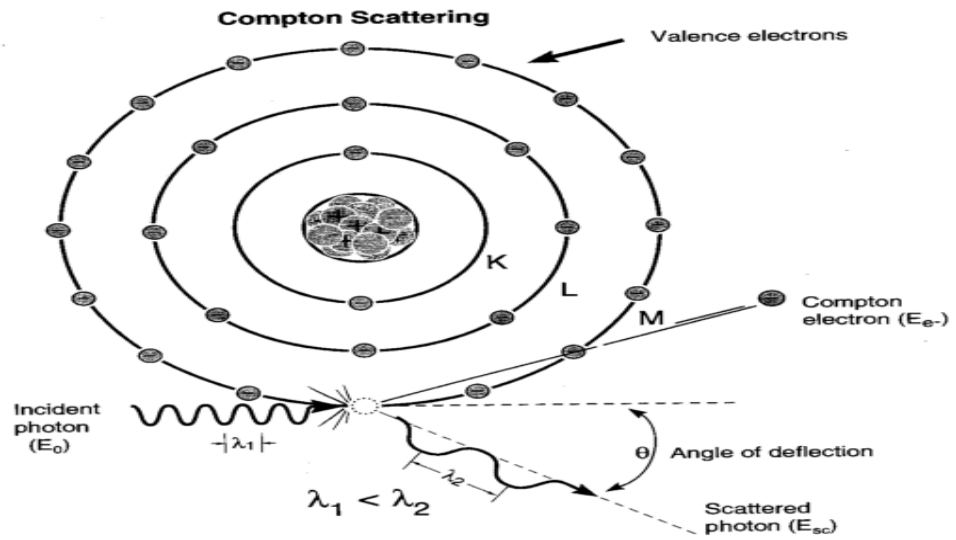
When traversing matter, photons will penetrate, scatter, or be absorbed. There are four major types of interactions of x- and gamma-ray photons with matter, the first three of which play arole in diagnostic radiology an: (a) Compton scattering, (b) photoelectric absorption, and (c) pair production(Bushberg et al.,2002).

2.3.1.1 Compton scatters:

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 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 (Fig. 2.4). The electron is ejected from the atom, and the photon is scattered with some reduction in energy. As with all types of interactions, both energy and momentum must be conserved.

Thus the energy of the incident photon (Eo) is equal to the sum of the energy of the scattered photon (Ese) and the kinetic energy of the ejected electron (Ee-), as shown

in Equation . The binding energy of the electron that was ejected is comparatively small and can be ignored(Bushberg et al.,2002).



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

Figure (2.4) show Compton scatters(Bushberg et al.,2002)

Compton scattering results in the ionization of the atom and a division of the incident photon energy between the scattered photon and 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, photoelectric absorption (to be discussed shortly)(Bushberg et al.,2002).

The energy of the scattered photon can be calculated from the energy of the incident photon and the angle of the scattered photon (with respect to the incident trajectory):

$$E_{sc} = \frac{E_o}{1 + \frac{E_o}{511\ \text{keV}}(1 - \cos\theta)}$$

where E_{sc} = the energy of the scattered photon,
E_o = the incident photon energy, and
θ = the angle of the scattered photon.

2.3.1.2 .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 photo-electron (Ee) is equal to the incident photon energy (Eo) minus the binding energy of the orbital electron (Eb) .

$$E_e = E_o - E_b$$

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 inner shell 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 does not occur frequently for diagnostic energy photon interactions in soft tissue.

The probability of photoelectric absorption per unit mass is approximately proportional to Z3/E3, where Z is the atomic number and E is the energy of the incident photon. For example, the photoelectric interaction probability in iodine (Z =53) is (53/20)3 or 18.6 times greater than in calcium (Z = 20) for photon of a particular energy.

The benefit of photoelectric absorption in x-ray transmission imaging is that there are no additional nonprimary photons to degrade the image. The fact that the probability of photoelectric interaction is proportional to 1/E3 explains, in part, why image contrast decreases when higher x-ray energies are used in the imaging process . If the photon energies are doubled, the probability of photoelectric interaction is decreased eightfold: ('/2)3 = 1/8.

Although the probability of the photoelectric effect decreases, in general, with increasing photon energy, there is an exception. For every element, a graph of the probability of the photoelectric effect, as a function of photon energy, exhibits sharp discontinuities called absorption edges.

The probability of interaction for photons of energy just above an absorption edge is much greater than that of photons of energy slightly below the edge. For example, a 33.2-keV x-ray photon is about six times as likely to have a photoelectric interaction with an iodine atom as a 33.1-keV photon**(Bushberg et al.,2002)**.

2.3.1.3 Pair production:

Pair production can only occur when the energies of x- 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 electrons 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 is of no consequence in diagnostic x-ray imaging because of the extremely high energies required for it to occur.

In fact, pair production does not become significant unless the photon energies greatly exceed the 1.02 MeV energy threshold**(Bushberg et al.,2002)**

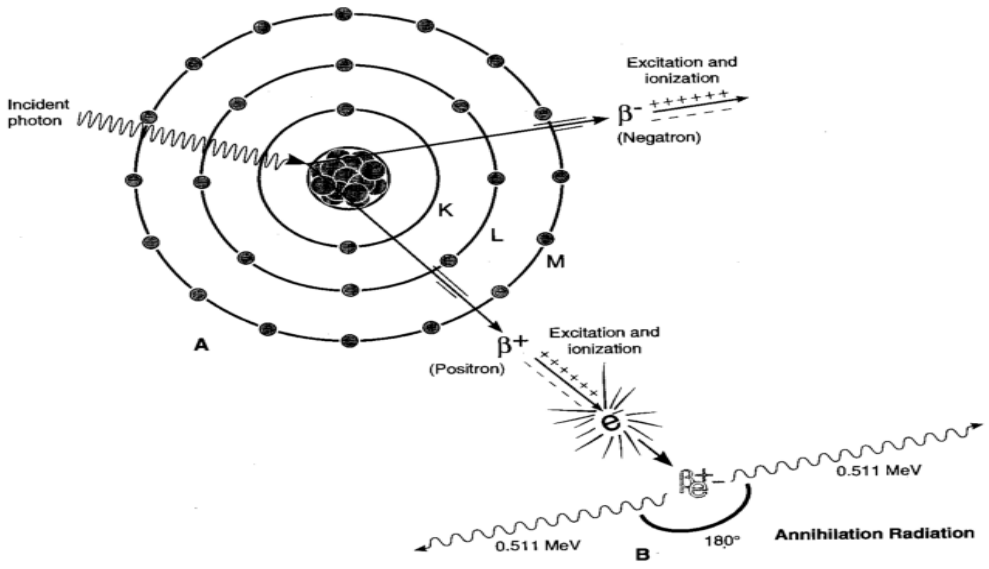


figure (2.5) show Pair Production(Bushberg et al.,2002)

2.4. Biological Effect of Ionizing Radiation:

The collective to the population resulting from medical exposure has been estimated to represent the largest single man-made contribution to both the somatic and the genetically significant dose equivalent in European countries. A similar distribution was found in other developed countries. The largest contribution being from Diagnostic Radiology, which estimated at ten times the sum of contributions from nuclear medicine and radiotherapy. It is desirable to reduce the patient dose in diagnostic radiology to minimum with good image quality to keep the dose as low as reasonably achievable (ALARA principle).(BUSHONG, et al, 2002).

Biological effects may occur in the exposed individual as somatic radiation damage to the cell or alternatively this genetic damage could be passed on to individual's descendants. The effects are classified into stochastic and deterministic effects.

2.4.1. Stochastic Effects:

Short-term effects may arise soon after exposed to radiation. The effect may subside quickly. These effects generally manifest many years, even decades, after the radiation exposure (and were once called “late effects”). Their major characteristics, in direct contrast with those for non stochastic effects, are:

1. A threshold may not be observed.

2. The probability of the effect increases with dose.

3. You cannot definitively associate the effect with the radiation exposure (Van Rooyen et aI., 1995).

2.4.2. Deterministic effects:

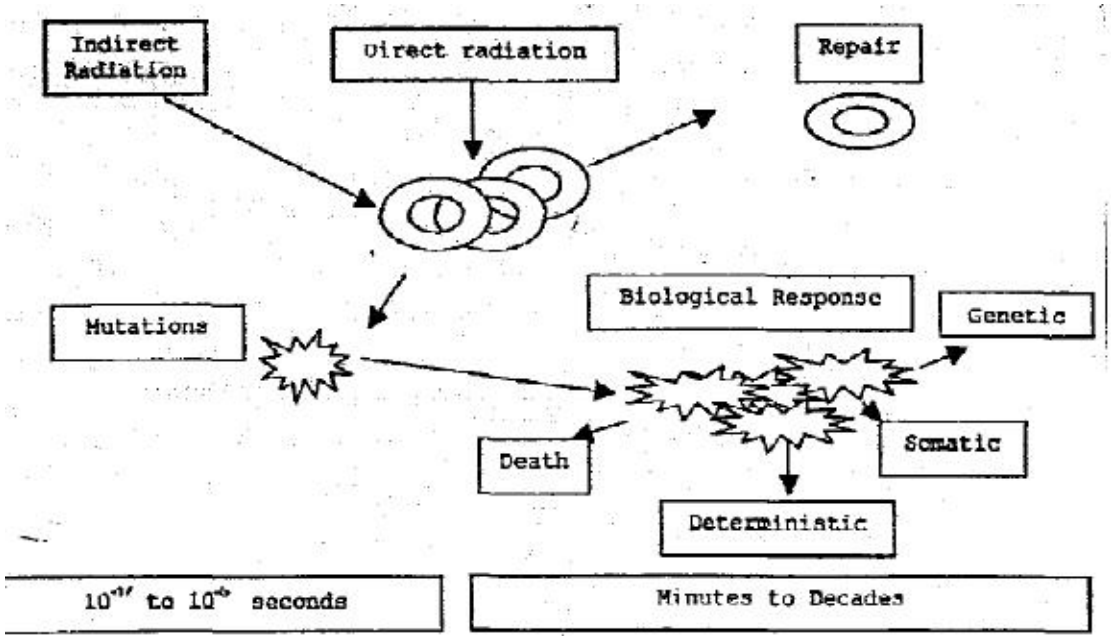
In deterministic effect there is a threshold dose of radiation below, which the effect does not occur. Doses significantly above the threshold will produce effects which severity is proportional to the absorbed dose received. Short-term effects are: radiation erythema, gastro-intestinal syndrome where the cell renewal system is damaged (Van Rooyen et al., 1995).

The major identifying characteristics of non stochastic Effects are:

1. There is a threshold of dose below which the effects will not be observed.

2. Above this threshold, the magnitude of the effect increases with dose.

3. The effect is clearly associated with the radiation exposure.



The figure (2.6) show the process of cell damage from the time of irradiation (Bushberg et al.,1997)

2.5. X-Ray Detectors:

The detection of x-ray is based on various methods. Before digital imaging was used the conventional film-screen system was the most commonly known method. Now a day this technique has been replaced by computed radiography (CR) and flat panel technology (HALL, E.J, 2002).

2.5.1 The modern film-screen detector:

System used for general radiography consists of cassette, one or two intensify screens, and a sheet of film. The film itself is a sheet of thin plastic with photosensitive emulsion coated on to one or both sides. Film can be used to detect x-rays but it is relatively insensitive and therefore a lot of x-ray energy is required to produce a properly exposed x-ray film. To reduce the radiation dose to the patient, x-ray screens are used in all modern medical diagnostic radiography. Screens are made of a scintillation material, which is called a phosphor. When x-rays interact in phosphor, visible or ultraviolet (UV) light is emitted. This light given off by the screens that principally causes the film darkening; only about 5% of the darkening of the film is a

result of direct x-ray interaction with the film emulsion. Therefore film-screen detectors are considered an indirect detector. The emulsion of an exposed sheet of x-ray film is altered by the exposure to light and the latent image is recorded as altered chemical bonds in the emulsion, which are not visible. However this latent image is visible during film processing(HALL, E.J, 2002).

2.5.2. Computed Radiography (CR):

is a term for photo stimulable phosphor detector (PSP) systems. Phosphors used in screen-film radiography, when x-ray are absorbed by photo stimulable phosphors, some light is emitted, but much of the absorbed x-ray energy is trapped in the PSP screen and can be read out later. For this reason, PSP screens are also called storage phosphors of imaging plates. CR was introduced in the 1970. After exposing the CR cassette is brought to CR reader. In the CR reader the imaging plate is scanned by laser beam. The laser light stimulates the emission of trapped energy in the imaging plate, and visible light is released from the plate. To form the image, the light released from the plate is collected by photomultiplier tube (PMT)(HALL, E.J, 2002).

2.5.3. Flat panel detectors:

are newer detector technologies for computed radiography with fast-imaging capability. Two types of flat panel systems are used:

- **a-** Indirect flat panel detectors are sensitive to visible light. An x-ray intensify screen is used to convert incident x-ray to light, which is then detected by photosensitive detector elements.
- **b-** Direct flat panel detectors are made from a layer of photoconductor material. With direct detectors, the electrons released in the detector layer from x-ray interactions are used to form the image directly. Light photons from scintillation are not used(HALL, E.J, 2002).

2.6.Medical Imaging:

The technique relies on analyzing attenuation data of the object (patient) that undergoes X-rayexposure. Because, different materials (internal organs) experience different levels of X- ray intensity attenuation, an image corresponding to these properties can be readily created. The attenuation characteristics are governed by the so called Beer Lambert Equation.

X-ray imaging is particularly good for providing a contrast between soft and hard tissues, because the attenuation coefficient has a quite different value in both media; hence one of the first applications was to identify fractured bones.To operate as a diagnostic technique,

X-ray imaging needs a radiation source, a means of interactions between the X-ray beam and the object to be imaged, ways of registration of the radiation carrying information about the object, and finally the ability to convert that information into an electrical signal. Although, widely used and in expensive, standard X-ray technique has quite severe limitations. First 3D structures are collapsed into 2D images, leading to highly reduced image contrast. Second, it is difficult to image soft tissues due to small differences in attenuation coefficient. Finally, standard film based technology does not provide quantitative data and requires specialized training for accurate image assessment (.IAEA, 2007).

2.6.1. X-ray Imaging:

X-ray imaging utilizes the ability of high frequency electromagnetic waves to pass through soft parts of the human body largely unimpeded. For medical applications, X-rays are usually generated in vacuum tubes by bombarding a metal target with high-speed electrons and images produced by passing the resulting radiation through the patient’s body on to a photographic plate or digital recorder to produce a radiograph, or by rotating both source and detector around the patient’s body to produce a “slice”

image by computerized tomography (CT). Although CT scans expose the patient to higher doses of ionizing radiation the slice images produced make it possible to see the structures of the body in 3D.

In X-ray radiography images are produced by casting an X-ray shadow onto a photographic film or digital detector:

Like gamma rays, X-rays can travel through soft tissues in body with little attenuation and are only “stopped” by high density tissues such as bone. Radiograph:

 Fully exposed areas of film/detector appear black.

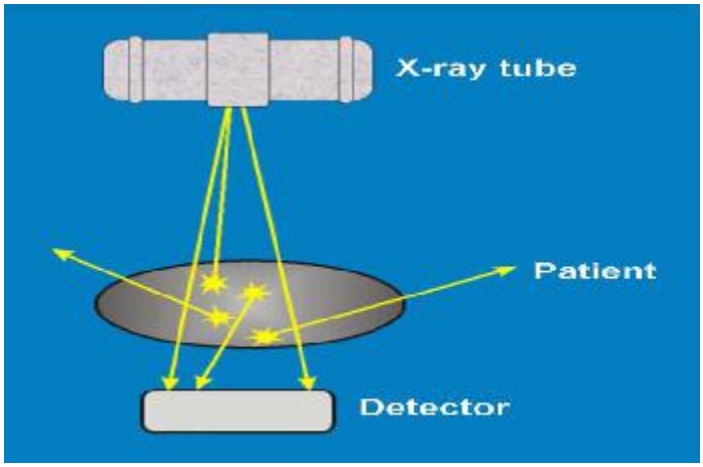
 Dense objects block more X-rays and so appear white.

 Soft tissues like fat and muscle result in intermediate exposure and so appear grey(H.E. Johns, 1993).

2.6.2. Projection radiography:

Projection radiography, the first radiologic imaging procedure performed, was initiated by the radiograph of the hand of Mrs. Roentgen in 1895. Radiography has been optimized and the technology has been vastly improved over the past hundred years, and consequently the image quality of today’s radiograph is outstanding. Few medical devices have the diagnostic breadth of the radiographic system, where bone fracture, lung cancer, and heart disease can be evident on the same image. Although, the equipment used to produce the X-ray beam is technologically mature, advancements in material science have led to improvements in image receptor performance in recent years projection imaging refers to the acquisition of a two dimensional image of the patient’s three dimensional anatomy. Projection imaging delivers a great deal of information compression, because anatomy that spans the entire thickness of the patient is concerning the lungs, the spine, the ribs, and the heart, because the radiographic shadows of these structures are superimposed on the image (H.E. Johns, 1983). The disadvantage isthat, by using just one radiograph, the

position along the trajectory of the X-ray beam of a specific radiographic shadow, such as that ofa pulmonary nodule, is not known. Radiography is a transmission imaging procedure. X-rays emerge from the X-ray tube, which is positioned on one side of the patient's body, they then pass through the patient and are detected on the other side if the patient by the detector (Figure 2.7), (H.E. Johns, 1983).



The figure (2.7) show the projective Radiology*: x-rays passing through the patients strike the Detector (*H.E. Johns, 1983*).*

2.6.3. Chest x-ray radiology:

Chest X-rays may be used to assess heart status (either directly or indirectly) by looking at the heart itself, as well as the lungs. Changes in the normal structure of the heart, lungs, and/or lung vessels may indicate disease or other conditions include heart enlargement (which can occur with congenital heart defects or cardiomyopathy), and "fluid in the lungs," known as pulmonary edema (which can occur with congenital heart disease or congestive heart failure) pneumonia and other lung diseases *(*H.E. Johns, 1983*).*

2.7. Radiation dosimetry:

Radiation dosimetry is the calculation of the absorbed dose in matter and tissue resulting from the exposure to indirectly and directly ionizing radiation. It is a

scientific subspecialty in the fields of health physics and medical physics that is focused on the calculation of internal and external doses from ionizing radiation.

2.7.1 Radiation quantities:

There are many different physical quantities that can be used to express the amount of radiation delivered to a human body. Generally, there are advantages and applications as well as disadvantages and limitations for each of the quantities. There are two types of radiation quantities: those that express the concentration of radiation at some point, or to a specific tissue or organ, and there are also quantities that express the total radiation delivered to a body. We will be considering each of these quantities in much more detail(IAEA, 2005). The general relationship between the concentration and total radiation quantities are illustrated below.

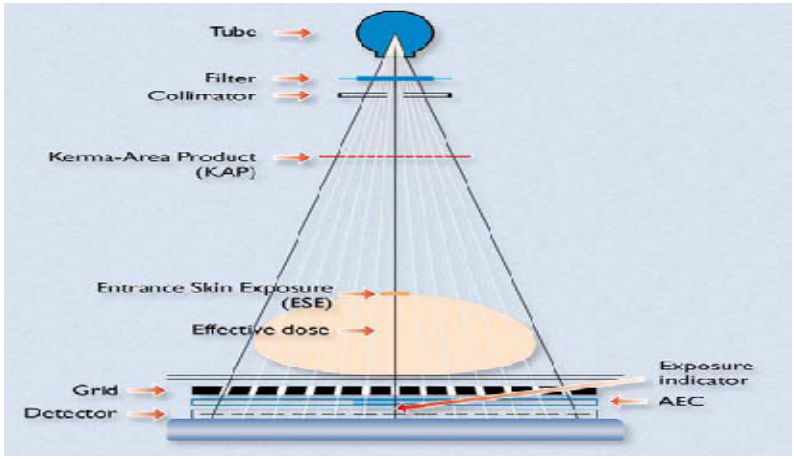


Figure (2.8) Typical examination beam geometry and related radiation dose quantities(IAEA, 2005)

2.7.1.1 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 is the roentgen (R) and the SI unit is the coulomb/kg of air (C/kg of air). The unit, the roentgen, 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. So, by measuring the amount of ionization (in coulombs) in a known quantity of air the exposure in roentgens can be determined(IAEA, 2005).

2.7.1.2. 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, the gray (Gy)(IAEA, 2005).

2.7.1.3. 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 is most directly related to biological effects. Dose values can be in the traditional unit of the rad or the SI unit of the 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(IAEA, 2005).

2.7.1.4. Entrance Surface dose:

Entrance skin exposure is defined as the exposure in roentgens at the skin surface of the patient without 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-ray beam, or the beam's penetrating power, therefore, entrance skin exposure is poor indicator of the total energy imparted to the patient(NRPB, 1999).

2.7.1. 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-ray beam axis at the point where x-ray beam enters the patient or a phantom, including the contribution of the backscatter (NRPB, 1992). The ESD is to be 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 or absorbed dose to tissue (NRPB, 1999).

2.7.1.6.Equivalent dose H_T :

Accounts for biological effect per unit dose

$$H_T = W_R x D$$

Table 2.1 Radiation weighting factors (W_R):

Radiation type and energy range	weighting factors (W_R):
Photons (X-rays and gamma-rays) all Energies	1
Electron all Energies Neutrons	1
<10 keV	5
10-100 keV	10
>100 kev to 2 MeV	20
2-20 MeV	10
>20 MeV	5
Protons >20MeV	5
Alpha particles , Fission fragments	20

2.7.1.7. Effective dose : E :

Risk related parameter, takingrelative *radiosensitivity* ofeach organ and tissue into account :

$E(Sv)= \Sigma_T W_T \times H_T$

W_T : tissue weighting factor for organ T

H_T: equivalent dose received by organ or tissue T

Table 2.2 Tissue and organ weighting factors (UNSCEAR 2008) :

weighting factors for different organs			
Tissue	Tissue weighting factors		
	ICRP 30(136) 1979	ICRP 60(13) 1991	ICRP 103(16) 2008
Gonads	0.25	0.20	0.08
Red bone marrow	0.12	0.12	0.12
Colon	-	0.12	0.12
Lung	0.12	0.12	0.12
Breast	0.15	0.05	0.12
Esophagus	-	0.05	0.04
Thyroid	0.03	0.05	0.04
Skin	-	0.01	0.01
Bone surfaces	0.03	0.01	0.01
Salivary glands	-	-	0.01
Brain	-	-	0.01
Remainder	0.30	0.05	0.12

2.8. Radiation Units:

2.8.1. Roentgen:

The roentgen 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. One roentgen is equal to depositing in dry air enough energy to cause 2.58 x 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 in air, and only for gamma and x-rays(Avenue, 2002).

2.8.2. 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. One 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(Avenue, 2002).

2.8.3. Rem (roentgen equivalent man):

The rem is a unit used to derive 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 thousandths of a rem, or mrem. To determine equivalent dose (rem), you multiply absorbed dose (rad) by a quality factor (Q) that is unique to the type of incident radiation.

2.8.4. 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 some material, and is used for any type of radiation and any material. 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 hundredths of a gray, or centi-grays. One gray is equivalent to 100 rads.

2.8.5. Sievert (Sv):

The sievert is a unit used to derive 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 millionths of a sievert, or micro-sievert. To determine equivalent dose (Sv), you multiply absorbed dose (Gy) by a quality factor (Q) that is unique to the type of incident radiation. One sievert is equivalent to 100 rem (Thayalan,2001).

2.8.6. Calculation of ESD from Exposure Factors:

ESD may be calculated in practice by means of knowledge of the tube output (Toivonen, 2001). The relationship between x-ray unit current time product (mAs) and the air kerma free in air is established at a reference point in the x-ray field at 80 kVp tube potential. Subsequent estimates 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 according to the following equation (Toivonen, 2001).

$$ESD = OP \times \left(\frac{kV}{80}\right)^2 \times mAs \times \left(\frac{100}{FSD}\right)^2 \times BSF$$

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 kVp, kV is peak tube voltage (kVp) recorded for any given examination (in many cases the output is measured at 80 kVp, 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 kVp. The value of 80 kVp should be substituted with whatever kVp the actual output is recorded at in any given instance). mAs is 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.

2.9. Radiation measurements:

With respect to measurement, three separate features of an X-ray beam must be identified .The first consideration is the flux of photons travelling through air from the anode towards the patient .The ionization produced by this flux is a measure of the Radiation exposure. If expressed per unit area per second it is the intensity of more fundamental importance as far as the biological risk is concerned is the absorbed dose of radiation. This is a measure of the amount of energy deposited as a result of ionization processes.

2.9.1 Dose measurement:

There are several ways of measuring doses from ionizing radiation. Workers who come in contact with radioactive substances or may be exposed to radiation routinely carry personal dosimeters. In the United States, these dosimeters usually contain materials that can be used in thermo luminescent dosimeter (TLD) or optically stimulated luminescence (OSL). Outside the United States, the most widely used type of personal dosimeter is the film badge dosimeter, which uses photographic emulsions that are sensitive to ionizing radiation. The equipment used in radiotherapy (linear particle accelerator in external beam therapy) is routinely calibrated using ionization chambers or the new and more accurate diode technology (EPA, 2006).

2.9.1.1. Ionization chamber:

In medical x-ray imaging the Free-in-air air kerma measurements are best made with suitably designed ionization chambers of typically between 0.6 and 180 cm3 volume. The chambers should have ‘air equivalent’ walls so that their energy response in terms of air kerma is substantially uniform for all relevant x-ray spectra. The leakage current should be very small compared with the ionization current produced by the minimum dose rate to be measured and the response should not be affected appreciably by ion recombination at high dose rates. Dosimeters should be calibrated in a manner traceable to a national primary standard of air kerma as described; there are special requirements for ionization chambers used for air-kerma measurements in mammography: these are a thin entrance wall to reduce attenuation at low photon energies, and ideally a structure that does not appreciably disturb the primary radiation field. Thin entrance window chambers with small volumes generally have a rather massive construction on the exit side, which implies that the charge produced in the cavity contains a significant contribution from scattered radiation (HALL, 2002).

2.9.1.2 Dose -area product meters:

Dose area product is defined as the absorbed dose to air averaged over the area of the X-ray beam in a plane perpendicular to the beam axis multiplied by the area of the beam in the same plane. It is usually measured on Gy cm2 and radiation backscattered from the patient is excluded Provided that the cross sectional area of the beam lies completely within the detector, it may be shown by simple application of the inverse square law that the reading will not vary with the distance from the tube focus.

Thus the dose area product can be measured at any point between the diaphragm housing on the X-raytube and the patient, but not so close to the patient that there is significant backscattered radiation.

Dose area product meters consist of flat, large area parallel plate ionization chambers connected to suitable electrometers which respond to total charge collected over the whole area of the chamber .The meter is mounted close to the tube focus where the area of the X-ray beam is relatively small and dose rates are high. It is normally mounted on the diaphragm housing whereit does not interfere with the examination and is usually transparent so that when fitted to an over –couch X-ray tube the light beam diaphragm device can still be used (Avenue, 2002).

2.9.1.3. Thermo Luminescent Dosimetry:

Many crystalline materials exhibit phenomena of thermo luminescence .When such a crystal is irradiated, a very minute fraction of the absorbed energy is stored in crystal lattice. Some of this energy can be recovered latter as visible light if the material is heated. This phenomena of release of visible photon by thermal means is known as thermoluminescence.(Thayland, 2001).

2.9.2. Direct measurement of entrance surface dose:

ESD is defined as the absorbed dose to air at intersection point of the X-ray beam axis with the entrance surface of the patient, including backscatter radiation. This does is expressed in mGy. The most straight forward method for skin dose determination is to put TLDs or other detectors on the patients' skin. However, the choice of the methods and dosimeters are not yet clearly established. In this section an overview is given of the measurement of the maximum skin dose D skin, local during radiological examinations. Although most of the measurements were actually performed with TLDs, scintillation dosimeters and film dosimeters have also been used. Semiconductor dosimeters [diodes or metal oxide semiconductor field effect transistors (MOSFETs)] have been used only for phantom. The ESD is estimated in

order to assess the possibility of skin dose exceeding the threshold for deterministic effects. The total values of imparted radiation dose from all fluoroscopic and radiographic exposures involved in the specific examination .ESD depends on the exposure parameters (Tube voltage, Total filtration, mAs andFFD), and patient's conditions (patient positioning, field size, and film screen system (Thayalan,2001)

2.10. Previous studies:

M.A. Halato et al , 2008 estimated the entrance skin doses ESDs for patients undergoing selected diagnostic X–ray examinations in two large public hospitals in Khartoum state, Sudan. The study included the examinations of the chest postero-anterior (PA) , skull antero-posterior (AP), skull Lateral (LAT) , Lumber spine AP/LAT, abdomen Intravenous urogram (IVU) and Pelvis AP. Totally, 241 patients were included in this study. ESDs were estimated from patients' specific exposure parameters using established relation between output (μGy/mAs) and tube voltage (kVp). The estimated ESDs ranged from 0.18 - 1.05 mGy for chest PA, 0.98 - 3.48 mGy 25 for Skull (AP), 0.66 - 2.75 mGy for skull (LAT), 1.22 - 4.35 mGy for abdomen (IVU), 1.18 - 5.75 mGy for Pelvis, 1.52 - 5.01 mGy Lumbar spine AP and 2.48 - 10.41 mGy for Lumbar spine (LAT). These values compare well with the international reference dose levels. This study provides additional data that can help the regulatory authority to establish reference dose level for diagnostic radiology in Sudan.

Mhamadain K. E. M et al 2004 estimated the entrance skin dose (ESD), the body organ dose (BOD) and the effective dose (E) for chest x-ray exposure of pediatric patients in five large units, three in Sudan and two in Brazil, and to compare the results obtained in both countries with each other and with other values obtained by some European countries. Two examination projections have been investigated, namely, postero-anterior (PA) and antero-posterior (AP). The age intervals considered

were: 0-1 year, 1-5 years, 5-10 years and 10-15 years. The results have been obtained with the use of a software called DoseCal. Results of mean ESD for the age interval 1-5 years and AP projection are: 66 μGy IPPMG Hospital), 41, 86 and 68 μGy (IFF Hospital), 161 μGy (Omdurman Hospital), 395 μGy (Khartoum Hospital) and 23 μGy (Ahmed Gasim Hospital). In the case of the IFF Hospital, the results refer, respectively, to rooms 1, 2 and for the six mobile equipments. The mean E for the same age interval was 11 μSv in the IPPMG, 6, 15 and 11 μSv in the IFF, respectively for rooms 1, 2 and the 6 mobiles, 25 μSv in the Omdurman Hospital, 45 μSv in the Khartoum Hospital and 3 μSv in the Ahmed Gasim Hospital.

Osman 2010, measured patient dose in routine X-ray examinations in Omdurman teaching hospital Sudan.A total of 110 patients were examined and 134 radiographs were obtained in two X-ray 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 lumber spine, were; 231±44 μGy,716±39 μGy, 611±55μGy, respectively. Also he has shown his data results comparable with previous study in Sudan and Brazil . Osman, 2010 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.

(Armpilia et al 2002) measured the quantities and risk in neonates in a special care baby unit. This survey aimed oto determine the radiation doses to neonates from diagnostic radiography (chest and abdomen) has been carried out in the special care baby unit of the Royal Free Hospital. Entrance surface dose (ESD) was calculated from exposure parameters, was found to range from 28 μGy to 58 μGy, with a mean

ESD per radiograph of 36±6 μGy averaged over 95 examinations.

Brennan et al 2000 the study was to establish a reference doses for paediatric radiology as a function of patient size. Five standard sizes of patient have been chosen at ages 0 (newborn), 1, 5, 10 and 15 years. Standard AP and lateral thickness for the head and trunk for the reference ages were derived from published measurements on children. Normalization factors for entrance surface dose and dose-area product measurements were calculated which depend on the 26

thickness of the real patient, the thickness of the nearest standard 'patient', and an effective linear attenuation coefficient (μ). These normalization factors were applied to European data to derive some preliminary reference doses.

Chapter Three

Materials and Methods

3.1Materials:

3.1.1.Equipments:

In the present study, two different modalities X-ray machines, from different manufacture were used.

3.1.2.Patient:

A total of 100 patients were examined in two radiology departments in Alshab teaching hospital. The data were collected using a sheet for all patients in order to maintain consistency of the information. The following parameters were recorded age, weight, height, body mass index (BMI) derived from weight (kg)/ (height (m)) and exposure parameters were recorded. The dose was measured for chest x-rays examination. The examinations were collected according to the availability.

3.2. Methods

3.2.1. Study duration:

This study performed in period of May to November 2014

3.2.2. Study place:

This study conducted in Alshab Teaching Hospital and Omdurman Teaching Hospital.

3.2.3. Method of data collection

This study involved patients undergoing chest radiographic examinations in the emergency department at Alshab Teaching Hospital. The radiographic equipment used was Shimadzo imaging system. It has a Polydoros LX 50 Lite high frequency generator with a general radiographic X-ray tube Opti 150/30/50HC. The target angle for the X-ray tube was 12°, and the measured ripple for tube potential was in the region of 1%. Total filtration for the X-ray system was measure as 2.7 mm of aluminum equivalent. A single exposure control system was available for use in the standing position.

3.2.4. Dose measurement:

ESD which is defined as the absorbed dose to air at the center 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 from formula below:

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

Where:

(OP) is the output in mGy/ (mA) of the X-ray tube at 80 kV at a focus distance of 1 m normalized to 10 mA s, (kV) the tube potential,(mA) the product of the tube current (mA) and the exposure time(s), (FSD) the focus-to-skin distance (in cm). (BSF) the backscatter factor, the normalization at 80 kV and 10 mAs was used as the potentials across the X-ray 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, mA s, FSD and filtration) are initially inserted in the software. The kinds of examination and projection are selected afterwards.

3.2.5. Method of data analysis:

The data will analyze with SPSS program under windows with t-test to assess the significance of data BMI and exposure factor. ICRP dose calculation program will use to determine dose received by body organs.

3.2.6. Method of data storage:

The data stored securely in password personal computer (PC)

3.2.7. Ethical issue:-

- Permission from radiology department.

Chapter Four:

The Results

4.1. Results:

4.1.1 Alshab Teaching Hospital Results:

For the group of patients where age distribution was measured 42 % of patients were within the 15-35years age range, 30 % of patients were within the 36-55 years age range, 22 % of patients were within the 56-75years age range, 06 % of patients were within the 76-95 years age range. The key parameters for this group are shown in Table 4-1.

Table 4-1 show the age distribution for both gender among the study sample

Age Group (years)	Male	Female
15-35	**26%**	**16%**
36-55	**16%**	**14%**
56-75	**22%**	**00%**
76-95	**02%**	**04%**

For the group of patients where Body Mass Index (BMI) was measured, 42 % of patients were within the 19.33 $\pm$ 4.95 (male), 23.36 $\pm$ 5.99 (female)BMI ratio range, 30% of patients were within the 25.23 $\pm$ 3.87 (male), 24.36$\pm$ 4.99 (female) BMI ratio range, 22 % of patients were within the 23.57 $\pm$ 4.17 (male), 00.00 $\pm$ 00.00 (female) BMI ratio range, 06 % of patients were within the 12.50 $\pm$ 00.00 (male) and 22.8 $\pm$ .85 (female) BMI ratio range. The key parameters for this group are shown in Table 4-2.

Table 4-2. Shows the mean and standard deviation of Body mass index distribution for both gender among the study sample

Age Group (years)	Body Mass Index (BMI) Ratio	
	Male	Female
15-35	19.33 ± 4.95	23.36 ± 5.99
36-55	25.23 ± 3.87	24.36± 4.99
56-75	23.57 ± 4.17	00.00 ± 00.00
76-95	12.50 ± 00.00	22.8 ± .85

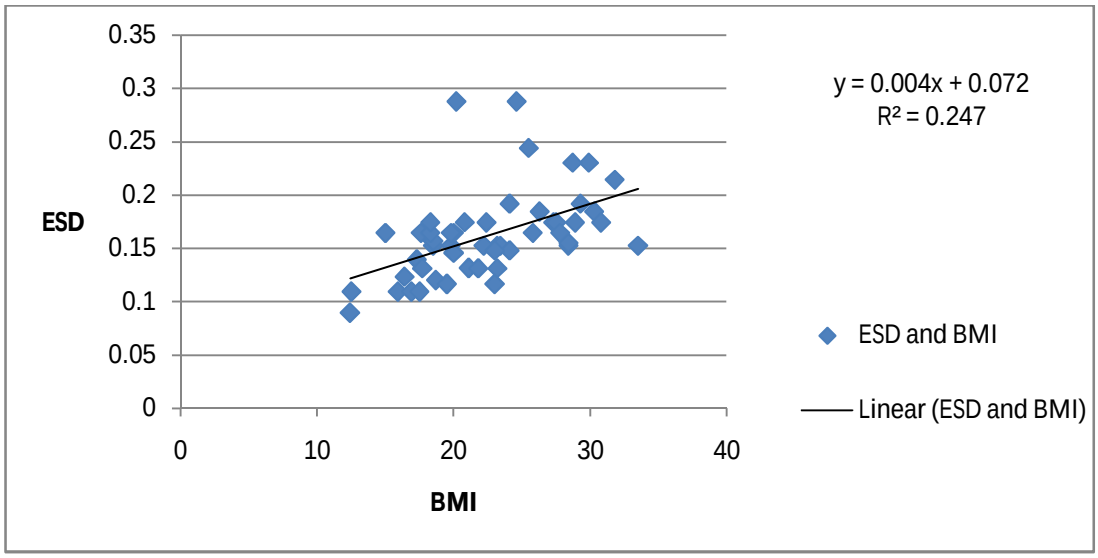


Figure 4-1. Correlation between entrance skin dose ESD (mGy) and body mass index BMI (Kg/m2) of patients undergoing Chest X-ray for ATH.

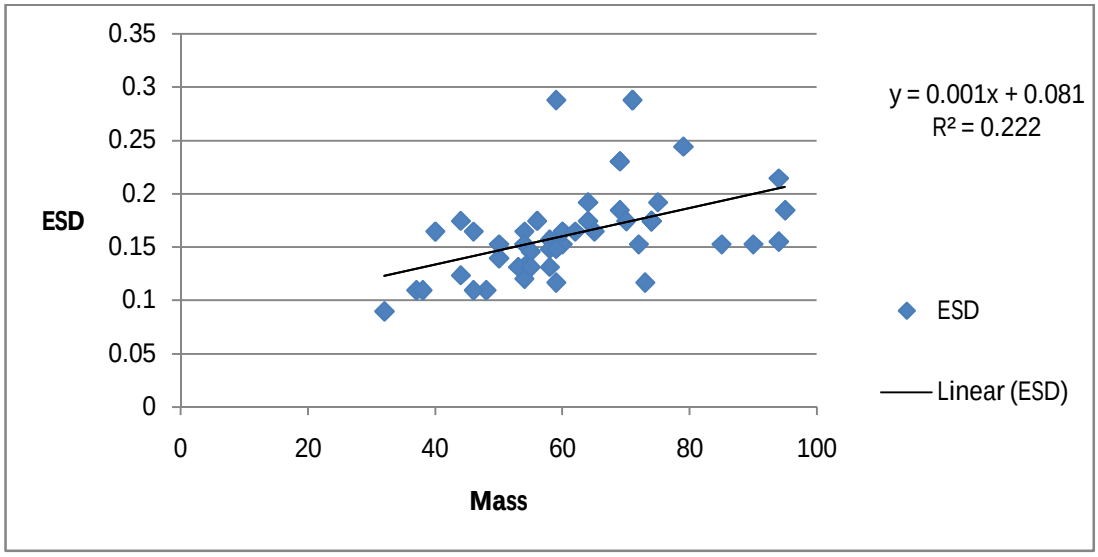


Figure 4-2: correlation between entrance skin dose ESD (mGy) and weight (mass) of the body (Kg) of patients undergoing chest X-ray for ATH.

For the group of patients where x-rays exposure factors (kVp and mAs) was measured, 42 % of patients were within the 68± 4.57 (kVp), 18.9± 3.64 (mAs)exposure factors ratio range, 30% of patients were within the 68.13± 2.67 (kVp) and 20.3± 2.84 (mAs) exposure factors ratio range, 22% of patients were within the 69.45± 4.57 (kVp) and 20.32± 4.17 (mAs) exposure factors ratio range, 06% of patients were within the 67.33±4.62 (kVp) and 17.00± .87 (mAs) exposure factors ratio range. The key parameters for this group are shown in Table 4-3.

Table 4-3. Shows the mean and standard deviation of exposure factors used for chest examination in the study sample for ATH.

Age Group (years)	*X-ray Exposure Factors (Mean ± Standard deviation)*	
	kVp	***mAs***
15-35	68± 4.57	18.9± 3.64
36-55	68.13± 2.67	20.3± 2.84
56-75	69.45± 4.57	20.32± 4.17
76-95	67.33±4.62	17.00± .87

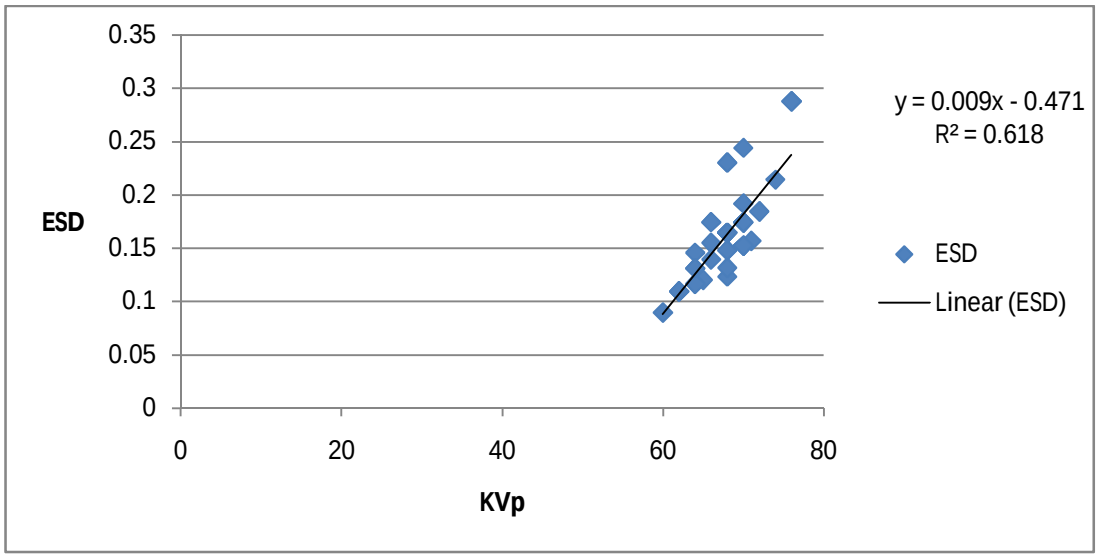


Figure 4-3: correlation between entrance skin dose ESD (mGy) and tube potential kVp to patients undergoing chest X-ray for ATH.

Table 4.4: Exposure factors, number of films and dose values for chest exam

Exam	**KVp**	**mAs**	**Time (sec.)**	**Films**	**Dose (mGy) (mean ± sd)**
Chest	67.92	19.52	0.21	1	.16±0.04

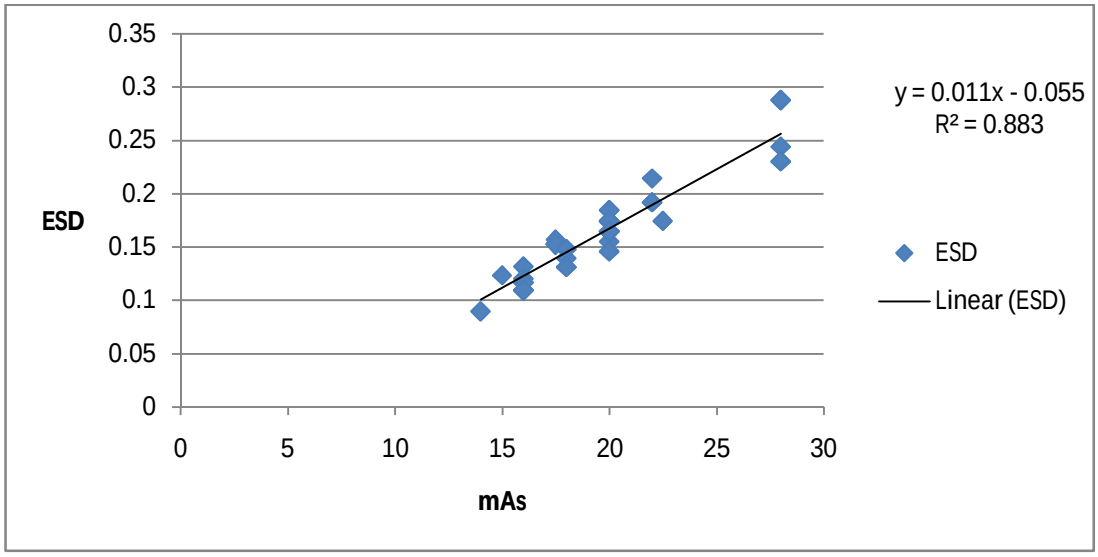


Figure 4-4: correlation between entrance skin dose ESD (mGy) and the product of the tube current (mAs) to patients undergoing Chest X-ray for ATH.

4.1.2. Omdurman Teaching Hospital Results

For the group of patients where age distribution was measured 36 % of patients were within the 15-35years age range, 40 % of patients were within the 36-55 years age range, 22 % of patients were within the 56-675years age range, 02 % of patients were within the 76-95 years age range. The key parameters for this group are shown in

Table 4-5 show the age distribution for both gender among the study sample

Age Group (years)	*Male*	*Female*
15-35	**26%**	**10%**
36-55	**14%**	**26%**
56-75	**20%**	**02%**
76-95	**02%**	**00%**

For the group of patients where Body Mass Index (BMI) was measured, 36 % of patients were within the 20.62±4.43 (male), 21.02±2.46 (female)BMI ratio range, 40 % of patients were within the 21.26±6.27 (male), 24.10±4.38 (female) BMI ratio range, 22 % of patients were within the 23.89± 5.08 (male), 25.40±0.00 (female) BMI ratio range, 02% of patients were within the 16.6± 0.00 (male) and 00.00± 0.00 (female) BMI ratio range. The key parameters for this group are shown in Table 4-6.

Table 4-6. Shows the mean and standard deviation of Body mass index distribution for both gender among the study sample

Age Group (years)	Body Mass Index (BMI) Ratio	
	Male	**Female**
15-35	20.62±4.43	21.02±2.46
36-55	21.26±6.27	24.10±4.38
56-75	23.89± 5.08	25.40±0.00
76-95	16.6± 0.00	00.00± 0.00

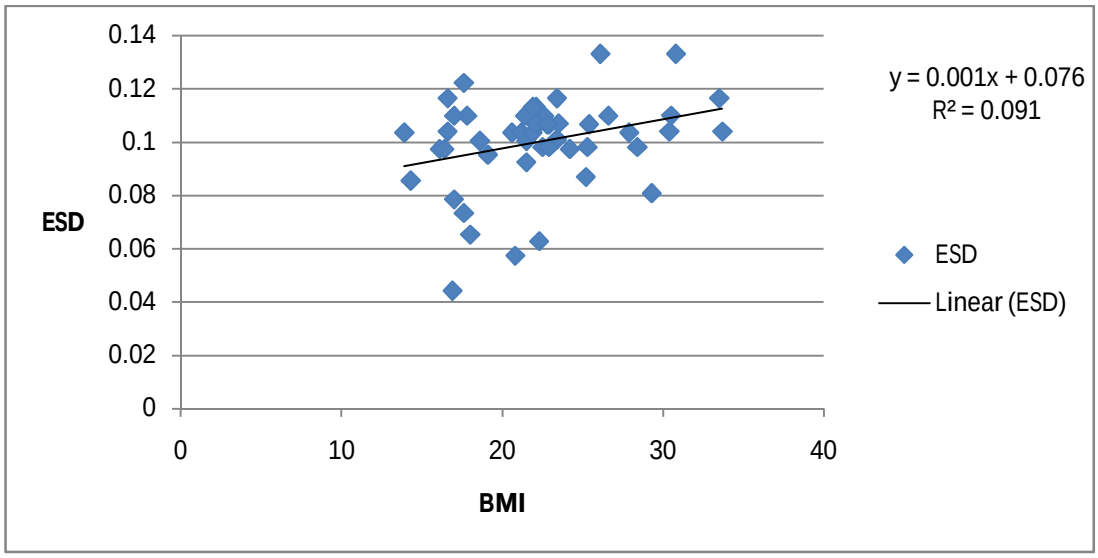


Figure 4-5. Correlation between entrance skin dose ESD (mGy) and body mass index BMI (Kg/m2) of patients undergoing Chest X-ray for OTH.

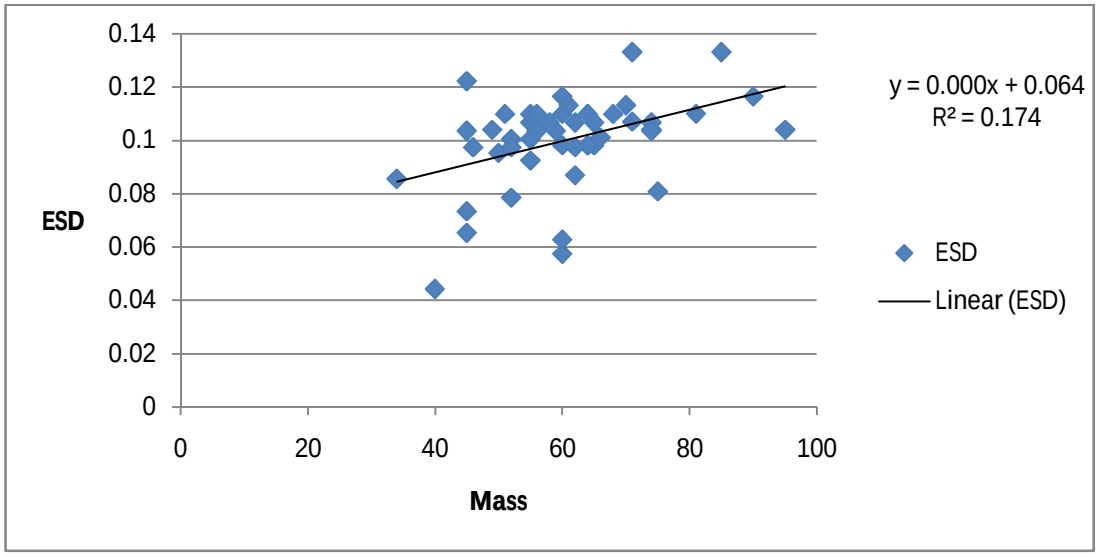


Figure 4-6: correlation between entrance skin dose ESD (mGy) and weight (mass) of the body (Kg) of patients undergoing chest X-ray for OTH.

For the group of patients where x-rays exposure factors (kVp and mAs) was measured, 36 % of patients were within the 69.61±12.98 (kVp), 12.53±2.29 (mAs) exposure factors ratio range, 40 % of patients were within the 66.80±02.31 (kVp) and 13.15±2.10 (mAs) exposure factors ratio range, 22 % of patients were within the 68.00±2.28 (kVp) and 12.86±2.20 (mAs)exposure factors ratio range, 02% of patients were within the 70.00±0.00 (kVp) and 12.50±0.00 (mAs) exposure factors ratio range. The key parameters for this group are shown in Table 4-7.

Table 4-7. Shows the mean and standard deviation of exposure factors used for chest examination in the study sample

Age Group (years)	X-ray Exposure Factors (Mean ± Standard deviation)	
	kVp	**mAs**
15-35	69.61±12.98	12.53±2.29
36-55	66.80±02.31	13.15±2.10
56-75	68.00±2.28	12.86±2.20
76-95	70.00±0.00	12.50±0.00

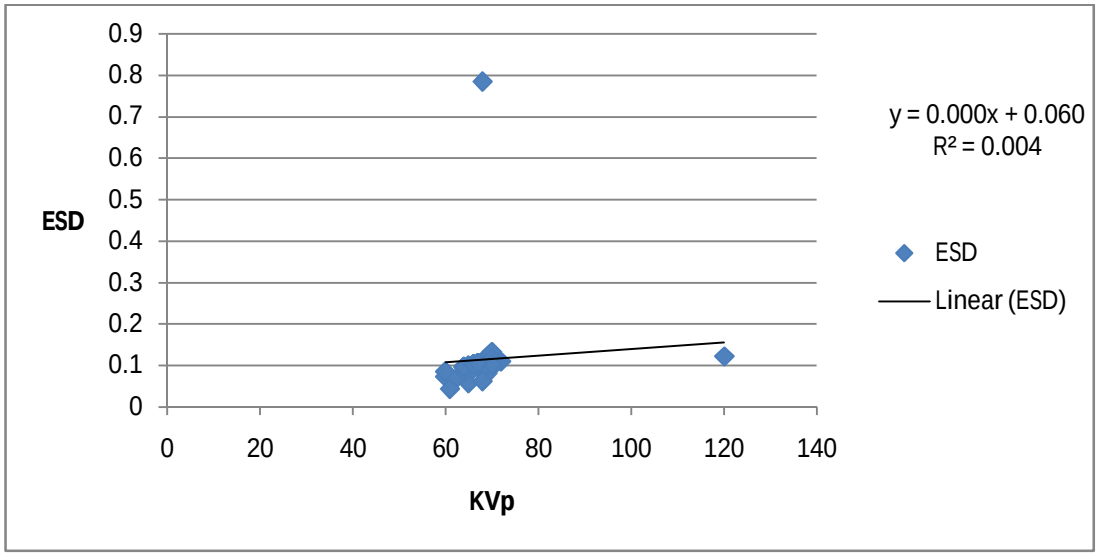


Figure 4-7: correlation between entrance skin dose ESD (mGy) and tube potential kVp to patients undergoing chest X-ray for OTH.

Table 4-8: Exposure factors, number of films and dose values for chest exam

Exam	KVp	mAs	Time (sec.)	Films	Dose (mGy) (mean ± sd)
Chest	68.14	12.85	0.21	1	.1±0.01

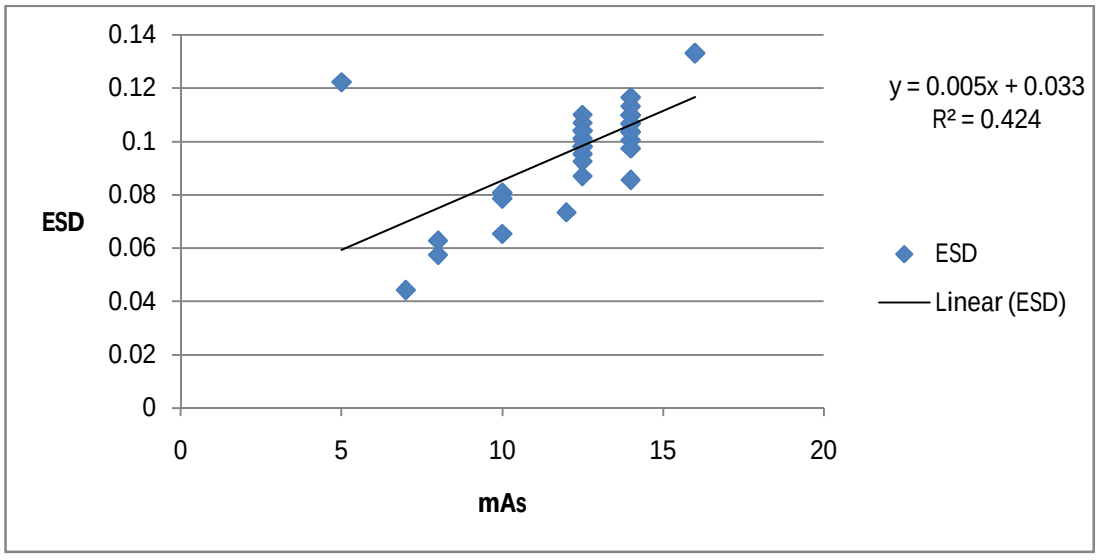


Figure 4-8: correlation between entrance skin dose ESD (mGy) and the product of the tube current (mAs) to patients undergoing Chest X-ray for OTH.

Chapter Five

Discussion, Conclusion and Recommendation

5.1 Discussions:

This study intends to evaluate the ESD in routine chest x-ray examination in Khartoum state. A total of 100 patients 50 in (ATH) and 50 in (OTH) were examined in the two hospitals. the relationship between X-ray unit current time product (mAs) , kVp and the ESDs was established at a reference point of 80 cm from tube focus for the range of current time product (mAs) and tube potentials encountered in clinical practice. The X-ray tube outputs, in mGy (mAs), were measured using Unfors Xi dosemeter (Unfors Inc., Billdal, Sweden).This dosimeter was calibrated by the manufacturer and reported to have accuracy better than 5%.For each patient all the following parameters were recorded: mean and standard deviation of exposure factors (kV, mAs) for two hospitals were recorded in tables (4.3, 4.7), and body mass index (BMI) of patient data (age, weight, height) for two hospitals were recorded in table (4.2, 4.6). The mean and standard deviation of exposure factors (kV, mAs) , dose in mGy and the number of radiographic films for the two hospitals were recorded in tables (4.4, 4.8).The correlation coefficient which is defined as a measure of the degree of linear relationship between two variables, usually labeled X and Y used in this study to describe the relation. These correlations coefficient between the patient dose ESD (mGy) against BMI, weight of the patients tube current time product (mAs) and tube voltage (kV) were obtained. Positive correlation coefficients were obtained between these values kv , mAs and the calculated ESDs values.The figures (4.1, 4.2, 4.5, 4.6, 4.7) shows that were no correlation found between the ESDs values and the weight and BMI in both hospitals (correlation coefficient R2 ranged from (0.004 to 0.247). The reason for the 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 comparison of the results of this study with those of the studies by Halato et al, Mhamadain et al 2004, Osman 2010 and with international dose reference levels for chest X-ray. ESDs for chest radiography in (ATH) hospital recorded in this study was (.16 $\pm$0.04) mGy, are in combarable with the values obtained in DRLs reported in European guidelines on quality criteria for diagnostic radiographic images Report EUR 16260EN which is the range mGy.The values of ESD recorded in (OTH) hospital was (.1 $\pm$0.01) mGy were lower by 62.5% than the values of ESD recorded in (OTH) hospital.These results indicate that a high degree of patient dose optimization was achieved in this study. The mean ESDs per chest radiographic image ranged between (.16 $\pm$0.04) and (.1 $\pm$0.01) mGy in (ATH) and (OTH) respectively per, which is slightly lower than the corresponding values reported in the DRLs reported in European guidelines on quality criteria for diagnostic radiographic images EUR 16260EN.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 study. The obtaining of differences in 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 is a source of concern.

5.2 Conclusion:

This study was intended to evaluate the radiation doses for patients undergoing diagnostic Chest X ray examinations in different two hospitals in Khartoum to help in applying radiation protection procedure of the patient. The most of the estimated ESDs values were within the range of reference level and below the range at some previous studies .The ESD depend on the exposure parameters and the machine wave form and filtration, Patient radiation dose is a very important parameter to control the quality of the X-ray services within the hospital. Dose monitoring helps to ensure the best possible protection of the patient and provides an immediate indication of incorrect use of technical parameters or equipment malfunction. Chest radiographs are the most commonly performed radiological exam. The patient dose was measured in two hospitals in different computed radiography modalities, the radiation dose was found higher in Alshab Teaching Hospital than Omdurman Teaching Hospital.The findings from 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 technology influence the patient doses and make medical staff aware of their responsibility for optimization of daily radiological practice.

5.3 Recommendation:

X-ray Radiography operator must optimize the patient dose by use the best strategies available for reducing radiation dose, the mAs reduction radiation dose and it have relation to patients size and weight and adapt the current based on patient size.X-ray Radiography must be used with high level of training for medical staff due to the high dose. Each radiology department should implement a patient dose measurement quality assurance program.Practical guidelines for better image quality in X-ray 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 in 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 must be established on the national scale, in order to reduce the patient exposure and to maintain a good diagnostic image.

Filtration and collimation of the x-ray beam are very important safety measures keep doses As Low as Reasonably Achievable (ALARA) principle in diagnostic radiology to reducing 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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