بسم الله الرحمن الرحيم

Sudan University of Science and Technology
College of Graduate Studies

Assessment of Radiation Dose Received from Lumbosacral Joint X-ray examination in Khartoum Teaching Hospital

تقييم الجرعة الإشعاعية الناتجة عن التصويرالشعاعى للمفصل القطني العجزي في مستشفى الخرطوم التعليمي

A complementary research submitted for partial fulfillment for the award of a master degree in Medical Physics

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2016

الايه

بسم الله الرحمن الرحيم

: قال الله تعالي

ففهمناها سليمان وكلا اتينا حكما وعلما وسخرنا مع داوود الجبال)

(يسبحن والطير وكنا فاعلين) (79

صدق الله العظيم

(سوره الانبياء الايه 79)

Dedication

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

To those of the fingers to give us a life of happiness.

My humble effort I dedicate to my sweet and lovely mother.

To reap the thorns out of my way for me to pave the way science

To heart the great my father

Whose affection, love, encouragement, and prays of day and night make me able to get such success and honor,

Along with all hard working and respected teachers

To my brothers, sisters, friends, and to all my family.

Acknowledgements

First of all I thank my almighty God (Allah), you have kept me alive and gave me power to do this work, I am so grateful. Secondly, I would like to thank everyone who has contribute in some way to my thesis. I am immensely grateful to **Mr. Awadh A. Adlan** for his guidance, inspiration and patience during my thesis period. As my doctoral advisor, he gave me a research project to make my own and pushed me to keep moving on to the next step. When things didn't work well, that wasn't a dead end, it was a reason to read and discover more, but he always made me feel as if I was on the right track. I truly appreciate his enthusiasm for new information, and I am thankful for the time we spent discussing it. For his motivation, assistance and for his immense support. I express my thanks and appreciation to staff, management, lecturers, and workers of College of Medical Radiological Sciences for making me feel as I was in my family, I appreciate this nice atmosphere, God bless them.

Many thanks to the best mum in the world (Altoma), to my brothers and sisters, their calls and prayers keep me strong, to the soul of my dad (Yousif) the best father, rest in peace. I express my appreciation to all my friends, especially to my colleagues at Sudan University of Science and Technology (SUST) and, thanks for their encouragement and support. I am also grateful for the amazing friendships I formed at College of Medical Radiological Sciences, especial thanks to Tamni youisf, Yasamin, and Hamdi thank for all the good discussions, all the inspiration they have given me, and for all the fun we have had!

Abstract

The objective of this study is to assess the entrance surface dose(ESD) received by patients undergoing radiological examinations of lumbosacral joint . The study was conducted at Khartoum Teaching Hospital (KTH). A sample of 50 adult patients were investigated over a period of two months using an X-ray unit (table 3.1, unit specifications) . Antero-posterior (AP) and lateral (Lat.) views were performed for lumbosacral joint and the data required for estimation the mean entrance surface dose (ESD) for both projections were recorded by the researcher (data sheet, appendix). The (ESD) for (AP) projections and (Lat.) projection were calculated using absorbed dose equation ,and the mean values were 4.8 mGy, and 10.35mGy respectively. The mean ESD for (AP) projection was 53.1% of the mean ESD for (Lat.) projection (Tables 4.1& 4.2).

For (AP) projection a weak correlation was shown between ESD and BMI ,KVp, and mass (insignificant), and there is a strong correlation between EDS and mAs (significant). For (lat) projection a weak correlation was shown between ESD and BMI, KVp, mAs, and mass (insignificant) .

الخلاصه

تهدف هذه الدراسه الي تقييم الجرعه السطحيه لمدخل الاشعه التي يتلقاها المرضي خلال التصوير الشعاعي للمفصل القطني العجزي .اجريت الدراسه في مستشفي الخرطوم التعليمي وشملت الدراسه 50 مريض اجريت لهم فحوصات اشعاعيه خلال شهرين واستخدم لهذا الغرض جهاز الاشعه السينيه .

تم تصوير المرضي في وضعيه اماميه خلفيه ووضعيه جانبيه للمفصل القطني العجزي وقد سجلت العلومات المطلوبه لحساب الجرعه بواسطه الباحث وتم حساب الجرعات الاشعاعيه باستخدام معادله الجرعه الممتصه لكل من الوضعين .

وقد خلصت الدراسه الي النتائج التاليه وهي ان قيمه الجرعه كانت 4.86 ملي قراي و 10.35 ملي قراي للوضعيتين الاماميه الخلفيه والجانبيه بالترتيب وقد وجد ان الجرعه للاسقاط الامامي الخلفي تساوي 53.1 % من قيمه الجرعه للاسقاط الجانبي .وهنالك ارتباط ضعيف بين الجرعه ومؤشر كتله الجسم وجهد الانبوب والكتله . اما الارتباط بين الجرعه وتيار الانبوب فقد كن قويا . بالنسبه للاسقاط الجانبي فان ارتباطا ضعيفا قد ظهر بين الجرعه ومؤشر كتله الجسم وجهد الانبوب وتيار الانبوب والكتله

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Khartoum Teaching hospital.	

List of abbreviations

ICRP International Commission on Radiological Protection

BSS Basic Safety Standard

IAEA International Atomic Energy Agency

ESD Entrance Surface Dose

ESAK Entrance Surface Air Kerma

OP Out Put

FSD Focus to Skin Distance

BSF Back Scatter Factor

BMI Body Mass Index

ED Effective Dose

Chapter one

1.1 Introduction:

Lumbosacral joint X-ray examination is one of the most frequently required diagnostic procedures used in clinical diagnostic radiology. It is an accepted imaging study for the diagnosis of pathological conditions in both children and adults. However, X-ray has inherent hazards that are of special concern when applied to young children. The lumbosacral X-ray examination can be carried out quickly and easily in an emergency department. The test can help to diagnose some lumbosacral conditions. Conventional X-ray diagnosis is a significant source of radiation exposure among the population. Therefore, there is the need for X-ray examinations to be conducted using techniques that keep the patients' exposure as low as possible, without affecting image quality. international commission on radiological protection (ICRP, 2007).

To be able to keep doses as low as reasonable achievable, it is necessary to understand the factors that influence patient doses and image quality. The Basic Safety Standard (BSS) (IAEA, 2011). Recommends optimization procedures in radiology for guidance. In the optimization of X-ray examination techniques, the patient dose should be characterized by a quantity that better accounts for radiation risk. Knowledge of organ and effective dose are necessary if the risk of radiation exposure is of concern. Patient dose is often described by the patient's entrance surface dose (ESD), which is measured on the patient's skin at the center of the X-ray beam. Radiation dose to the various organs or tissues in the body cannot be measured directly in patients undergoing X-ray examinations, but they can be estimated with reasonable accuracy if sufficient data on the X-ray examination parameters are available (Servomaa A, et al, 1998), (Tapiovaara M, et al, 1997).

1.2. Problem of the Study:

Radiation is a major risk in diagnostic medical imaging and therapy. The problem is caused by incorrect use of radiography equipment and from unnecessary radiation exposure to patients .International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) provide publications on protection from ionizing radiation . The report- 60 of the ICRP and the Basic Safety Standards that was published by the IAEA, contained three basic principles (justification, optimization, dose limits) related to the radiation protection (ICRP, 1991; IAEA, 1996).Exposure of different dose values for the same clinical examination is a reason to draw attention to this issue. Different dose levels are delivered to patients from different imaging techniques when performing lumbosacral joint examination.

1.3. Objectives of the study:

The main objective of this study is to assess the patient dose during lumbosacral examinations
hitch arise due to the routine imaging techniques.

1.3.1. Specific Objectives:

- To measure Entrance Surface Dose (ESD) for patients undergoing conventional lumbosacral X-ray examinations in Khartoum teaching hospital.
- To find the correlation between ESD and weight.
- To find the correlation between ESD and KVp.
- To find the correlation between ESD and mAs.

- To find the correlation between ESD and BMI.

1.4. Overview of the Study:

The study falls into five chapters, In chapter one, the researcher presents an introduction, a clear statement of the study problem and the objectives of the study. Chapter two, contains the background material for the study, 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 methods used to measure dose for routine radiography machines and explains in details the methods used for dose calculation, Chapter four deals with results and discussions and chapter five presents the conclusion and recommendations.

Chapter two

2.Background and literature review

X-rays are electromagnetic waves with wavelength of $10^{\wedge 4}$picometer (pm). The classical way of producing X-ray is by accelerating a high voltage electron beam in an X-ray 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-ray device, namely, the X-ray generator and the X-ray tube. In the section, a brief discussion on the role of the X-ray generator, then we introduce the main components of the X-ray tube.

2.1.1 X-ray generator:

The important role of the X-ray generator is to provide the X-rays tube with current to heat the cathode filament that provides the X-ray tube with voltage that accelerates the electrons towards 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, 2011)

2.1.2 X-ray tube:

An X-rays tube is made of different elements as shown in fig. 2.1, the cathode which is the source of electron beam, the anode which is bombarded by the electron beam to emit X-rays. all these structures are contained in evacuated glass tube to allow the electrons beam to travel in vacuum. A metallic tube housing is provided to protect 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 include a 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 X-rays tube consists of the target metal for fast electrons beams. Usually this target is also of 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 bombarded by the electron 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 current but gives low resolution, and a short filament which use high current gives high resolution .

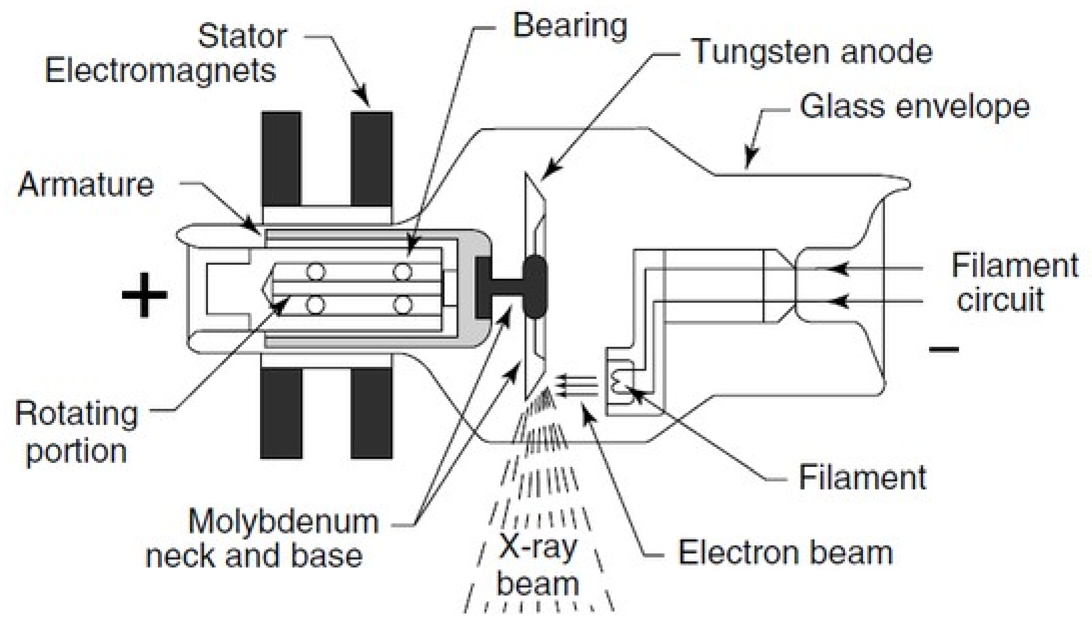
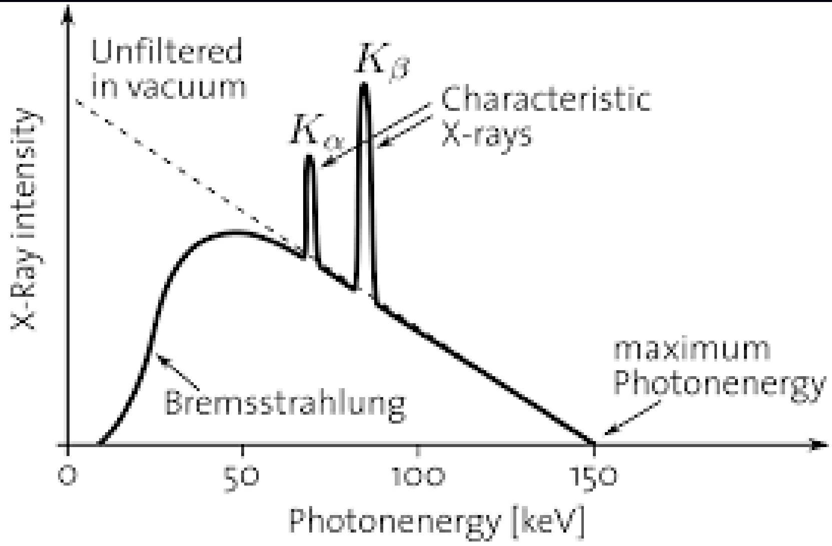


Figure 2.1: shows the component of x-ray tube (jaypee et al,2001).

2.2 X-ray beams:

The classical way of producing X-ray can be done through two different techniques. The first technique is by suddenly decelerating electron 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 inner shell of the atoms. Electrons make a transition from higher energy level to lower level and the difference between 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 columbic interactions between the incident electrons beam and the orbital electrons of the target material. The bombarding electrons can remove electrons from the inner shells of the target atoms producing vacancies. Electrons from the higher level drop down into 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). (LAEA, 2005).Characteristic X-rays spectrum shows discrete energy levels with peaks as presented in fig 2.2. these peaks occur when all these vacancies are produced in the K-shell (n=1) of the atom and electrons drop down into these vacancies. X-rays yield by transitions form L-shell (n=2) to K shell (n=1) levels is called K X-rays yield, by transitions form M-shell (n=3) to K-shell (n=1) levels are called K X-rays).



Figure(2.2: shows the X-ray beam(James E. Martin, 2006).

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 towards 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-ray 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 X-ray photon in matter. In this section the researcher presents a brief discussion on these interactions (James E. Martin, 2006).

2.3.1 Coherent scattering:

Coherent scattering, also known as classical scattering, occurs when a low energy X-ray 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 e effect:

Photoelectric effect, also known as photo effect, takes place when an X-ray photon interacts with a tightly bond orbital electron (from the inner shell). This photon attenuates and disappear 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, and the kinetic energy is given by :

$$\mathbf{E_k=h_v-E_b;}$$

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 which is used to overcome the electron binding energy and the remaining energy is transferred to the electron as kinetic energy

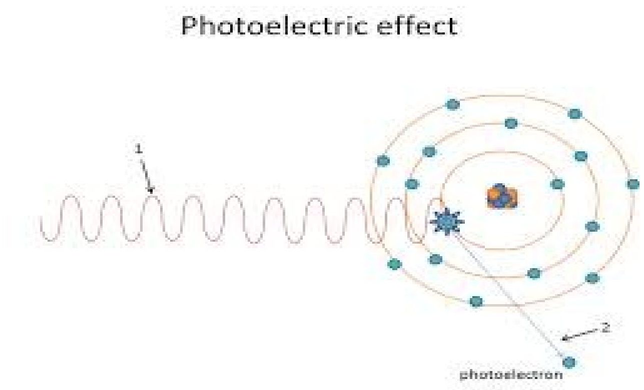


Figure 2.3: shows the photoelectric effect(James E.Martin ,2006), (Reilly Sutton,1997).

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, 0 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}.

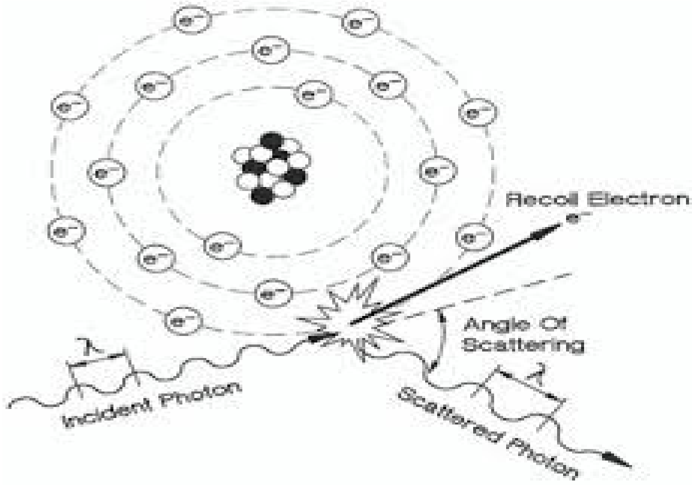


Figure 2.4: shows the Compton scattering (Reilly Sutton,1997).

2.3.4 Pair production:

This interaction takes place when a high energy photon (>1.02M_ve) 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 Columbic field and the photons disappears. The pair is produced with a combined kinetic energy following the equation below:

$$E_k=hv-2m_ec^2:$$

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 M_eV . 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.

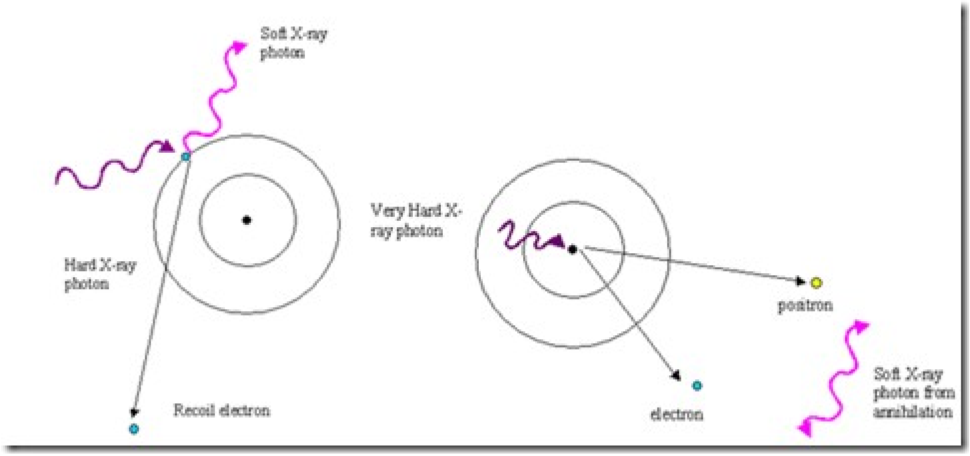


Figure 2.5: shows the pair production (James E. Martin, 2006).

2.3.5 Photodisintegration:

High energy X-ray photons with energies above 10 MeV can escape interacting with both the electrons and nucleus electrostatic fields. These photon 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 pair production, the high energy needed to cause this interaction make it less important in diagnostic radiography (Reilly Sutton, 1997), (IAEA,2007).

2.4 Effect of ionizing radiation:

Ionizing radiation is known to cause tissue 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.

2.4.1Deterministic 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 and damage to the intestines. Table 1-1 shows the potential effects of radiation.

Table 1.1: The potential effects of X-ray exposures on reaction of skin and lens of eye with data from ICRP publication 85.(Muthana AlGhazi, 2007).

Injury	**Threshold Skin(Sv)**	**Minutes fluoro at 0.02 Gy/min**	**Minutes fluoro at 0.2**
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 toeye

2.4.2 Stochastic effect:

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.(Jaypee brothers.newdelhi,2001)

Causes	Risk of death per year
Smoking 10 cigarettes/day	1in 200
Natural causes (40 years old)	1 in 850
Accidents on road	1 in 9500
Accidents at work	1 in 43500
Cancer from radiation exposure of 1mSv	1 in 25000

2.5 Radiation protraction methods

There are three basic methods to keep the radiation dose to patients, workers and the public as low as reasonably achievable. They are namely, minimizing the time of exposure, maximization of the distance to the radiation source, and use of appropriate shielding material (e.g. lead Pb and aluminum Al). These three principles 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 aims at keeping the radiation dose as low as reasonably achievable taking into consideration economic and social constraints. The goal of the ALARA Principle is to keep the radiation 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 cumulative (Thomas E. Johnson et al, 2012). The ALARA Principle is based on the linear Non-threshold (LNT) dose effect hypotheses, 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 effects associated with exposure (James E. Martin, 2006), (E P A O 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-ray beam passes through the human body, aportion of the beam is either absorbed or scattered by the internal structures (soft tissue or bones). And the remaining X-ray beam which passes through the body is transmitted to a detector (e.g. afilm 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 structures of none 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 type 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 procedure 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 monitor (a fluorescent screen or phosphor). This allows real-time monitoring 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 procedure e.g. during the operation to put some devices inside the body. However to reduce 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 from 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 radiologist to visualize the cross sectional view of the organ on a TV screen. This allows physicians to delineate the tumor and normal structure 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 tow dimensional attenuation projection image and the depth information of the structure 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 tow-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 side 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),(Muthana AlGhazi, 2007).

There are two types of CT scanners used in CT machines nowadays, namely, axial scanning and helical scanning. In the axial scanning, the patient table move 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:

$$\textbf{CT Number (HU) Tissue = 1000 x } \frac{\mu\, tissue\ pixel - \mu\, water}{\mu\, water}$$

The CT number gives an indication on the type of the tissue. Water has a CT number of zero, while negative CT number 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 value 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 application of X-rays:

Apart from medical discipline, many other applications of X-rays exist. In industry, X-ray 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 food 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 painting and for archaeological studies (Jaypee et al, 2001). X-rays are also use in security, for instance in airport around the world for quick checking the content of the airline baggage’s.

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 is 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 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 investigation of radiation effect require various specification of the radiation field at the point of interest. Radiation dosimeter 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 definition 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 .

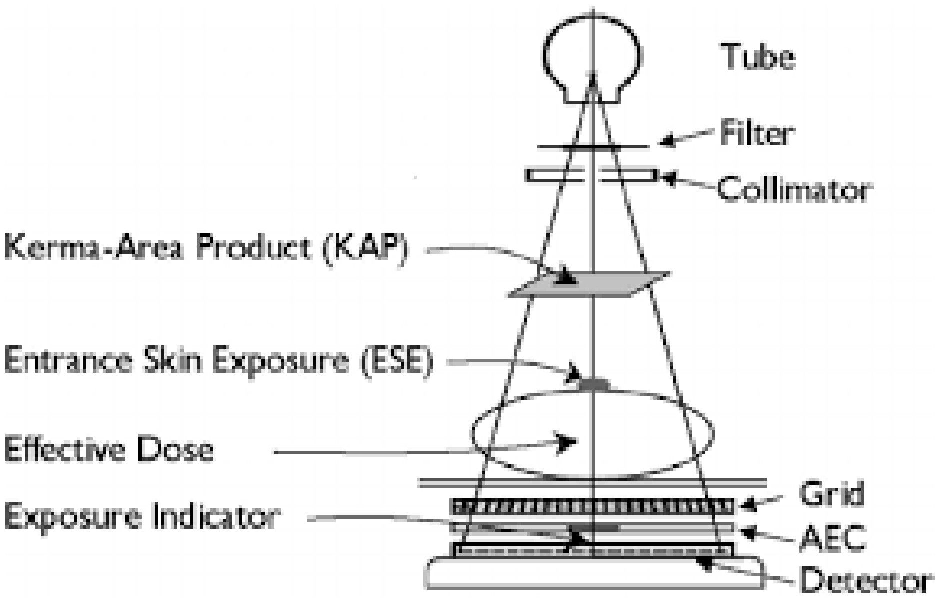


Figure 2.6: shows the radiation quantities (IAEA, 2005).

2.9.1. Exposure:

Exposure is 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 term 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 (jams 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 unit 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 value 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 measurement in 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 understanding 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 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 defied 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 examination, 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 exposure 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 (IR) is equal to depositing in dry air enough energy to cause $2.58x10^{4}$ coulombs per kg. it is a measure of the ionization 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 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 (Japee 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 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 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 to 100 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 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 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 measure 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 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 variation in patient doses between different radiological departments for the same type of examinations.

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 medical X-rays examination performed by GPs registered a 1% decreased between 1998and 2003. The study indicated also that the total number of all x-ray examination 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 examination, in order to optimize the radiological protection to the population in a cost-effective manner. Effective dose 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 examination 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 examination 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-rays examinations in Omdurman teaching hospital Sudan. A total of 110 patients were examined and 134 radiographs were obtained in to 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 lumber 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 Oliveraciraj et al. and henneranja respectively. And for lumbo-sacral spine AP and lateral it also reduced by factor of 59%, 90% 132%, 93% for study of Oliver Ciraj et al. and Kepler .k respectively.

Yousif, et al, 2012the study was performed in Khartoum teaching hospital, covering two x-ray units and a sample of 50 patients. The following parameters were recorded age, weight, height, body mass index (BMI) derived from weight (kg) and (height (m)) and exposure factors. The dose was measured for lumbosacral x-rays examination. For effective dose calculation, the entrance surface dose (ESD) values were estimated from the x-ray tube output parameters for Lumbosacral Spine AP and lateral examinations. The ED values were then calculated from the obtained ESD values using IAEA calculation methods. Effective doses were then calculated from energy imparted using ED conversion factors proposed by IAEA. The results of ED values calculated showed that patient exposure were within the normal range of exposure. The mean ED values calculated were 2.49 + 0.03 and 5.60 + 0.22 for Lumbosacral Spine AP and lateral examinations, respectively. Further studies are recommended with more number of patients and using more two modalities for comparison.

Chapter Three

Materials and Methods

3.1. Materials:

This study was done in Khartoum Teaching hospital. 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, and screen type and lm speed. To calculate the ESD, the radiographer was asked also to provide the typical exposure parameters used for 50 patients. The parameters were: peak tube voltage (kVp), exposure current-time product (mAs), focus-to- lm distance (FFD), the dose values were obtained with the use of the mathematical equation that provides the ESD. The calculation of ESD from output measurements and exposure factors is a realistic alternative method to (Thermolummesent dosimetry) TLD measurement.

3.1.1.Study group:

A total of 50 patients were examined in Khartoum Teaching Hospital. The data were collected using a sheet for every patient in order to maintain consistency of the information.

The following parameters weight, height, tube voltage, and tube current-time product setting exposure parameters were recorded.

3.1.2.machine used:

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

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

3.2. Methods:

3.2.1 Imaging technique:

For lumbosacral joint routine X-ray examinations consist of twoviews, the view antero - posterior (AP), and the lateral (lat) view.For lumbosacral x-ray preferred that the patient layout of table for this exam

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. Upper limbs radiography is the production of X-rays images of the fingers, hand, wrist, shoulder and elbow. Before the examination, the radiographer explained the procedure to all patients. While lower limbs radiography is the production of X-rays images of the foot, leg, ankle and knee joint. 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 (mAs) 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.

Chapter Four

The Results

The tables below show the mean value of weight, height, KV, mAs, BMI and ESD for the study sample in Khartoum Teaching hospital.

Table 4.1:shows the mean value of weight, height, KV, mAs, BMI and ESD for the (AP) projection of the study sample in Khartoum Teaching hospital.

NO	Projection	Weight	Height	KVp	mAs	BMI	ESD
50	P	57.06	164.95	76.54	33.38	24.946	4.864

Figure 4.1: Correlation between entrance skin dose ESD (mGy) and body mass
index BMI(Kg/m2) for the (AP) projection of the study sample in Khartoum Teaching hospital.

Figure 4.2: correlation between entrance skin dose ESD (mGy) and tube potential kVp for the (AP) projection of the study sample in Khartoum Teaching hospital.

Figure 4.3: correlation between entrance skin dose ESD (mGy) and the product of the time tube current (mAs) for the (AP) projection of the study sample in Khartoum Teaching hospital.

Figure 4.4: correlation between entrance skin dose ESD (mGy) and weight (mass) of the body (Kg) for the (AP) projection of the study sample in Khartoum Teaching hospital.

Table 4.2: shows the mean value of weight, height, KV, mAs, BMI and ESD for the (L) projection of the study sample in Khartoum Teaching hospital.

NO	Projection	Weight	Height	KVp	mAs	BMI	ESD
50	L	57.06	164.95	83.62	57.64	24.946	10.35

Figure 4.5. Correlation between entrance skin dose ESD (mGy) and body mass index BMI (Kg/m2) for the (L) projection of the study sample in Khartoum Teaching hospital.

Figure 4.6: correlation between entrance skin dose ESD (mGy) and tube potential kVp for the (L) projection of the study sample in Khartoum Teaching hospital.

Figure 4.7: correlation between entrance skin dose ESD (mGy) and the product of the time tube current (mAs) for the (L) projection of the study sample in Khartoum Teaching hospital.

Figure 4.8: correlation between entrance skin dose ESD (mGy) and weight (mass) of the body (Kg) for the (L) projection of the study sample in Khartoum Teaching hospital.

Chapter five

Discussion, Conclusion and Recommendations

5.1 Discussions:

This study intends to assessment the patient radiation dose in routine lumbosacral x-ray examination in Khartoum Teaching Hospital. A total of 50 patients 50 in (KTH) were examined in the one hospital. 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 KV meter.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 of exposure factors (kV, mAs) , BMI, Height, Weight and ESD for (AP) projection was recorded in table (4.1) and (L) projection was recorded in table(4.2). 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 betweenmAs and the calculated ESDs values.Negative correlation coefficients were obtained between KVp, BMI, Mass and the calculated ESDs values. The figures (4.1, 4.2, 4.4, 4.5, 4.6, and 4.8) shows that were no correlation found between the ESDs values and the KVp, weight and BMI in (correlation coefficient R2 ranged from (0.055 to 0.311). 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 figures (4.3 and 4.7) shows that there was correlation found between the ESDs values and the mAs.

ESDs for lumbosacral radiography in (KTH) hospital recorded in this study for (AP) projection was (4.864) mGy and (L) projection was (10.35)mGyand the ESD for (AP) projection was lower by 53.1% than the values of ESD for (Lat.) projection ,The mean value of ESD which obtain from this study was in accepted rang but higher than those which obtain from previous study but the.

5.2 Conclusion:

This study was intended to assessment the radiation doses for patients undergoing diagnostic lumbosacral examinations in Khartoum teaching hospital 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. The findings from the present study showed that optimization of technical and clinical factors may lead to a substantial patient dose reduction.

5.3 Recommendations :

X-rays Radiography practice should be optimized; this could be done by using the best strategies available for reducing radiation dose.

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.

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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