# Sudan University of Science and Technology

# College of Graduate Studies

## Estimation of Radiation Dose Received During Hystrosalpingography In Khartoum State Hospitals

## تقدير الجرعة الاشعاعية في تصويرالرحم و الانابيب في مستشفيات ولايه الخرطوم

A Thesis submitted for Partial Fulfillment for the requirement of (M.Sc) Degree
in Medical Physics

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قَالَ تَعَالَىٰ:

﴿ وَإِذَا مَرِضْتُ فَهُوَ يَشْفِينِ ﴾

**صُدِقَ ٱلْعَظِيمُ**

سورة الشعراء الاية{80}

# Dedication

To my father and mother

To my sisters and brothers

To my all family

To my teachers

To my friends

# Acknowledgement

I thank almighty God for giving me the strength, courage and determination in conducting this study, despite all difficulties.

Phrases may not cover what I mean to show, but a word must be penned to those who helped me and guided me through the way and to those who intended to help me accomplish this work .

I would like to thank gratefully my supervisor Dr. Ahmed Mostafa Abukonna

## List of abbreviation:

| **Abbreviations** | **Expression** |
|---|---|
| HSG | Hysterosalpingography |
| CT | Computed tomography |
| MRI | Magnetic resonance imageing |
| US | ultrasound |
| PET | Positron emission tomography |
| ICRP | International Commission on Radiological Protection |
| NRPB | National radiological protection board |
| ISO | International standard organizatin |
| ICRU | International comission on radiation units |
| ESD | Entrance skin dose |
| ESAK | Entrance surface air kerma |
| DAP | dose area product |
| TLDs | Thermo luminescent dosimeters |
| OP | Out put factor |
| FSD | Focal Skin Distance |
| CM | Contrast medium |
| BSF | Back Scatter Factor |
| LNT | Linear Non-threthold |
| mGy | Mali gray |
| μGy | Micro gray |
| KVp | Kilovoltage peak |
| mAs | exposure current time product |

| | |
|---|---|
| FFD | focus-to-film distance |
| CR | computed radiography |
| HU | Hounsfield units |

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# Abstract

Hysterosalpingography (HSG) is an effective method to evaluate abnormalities of the uterus and fallopian tube using conventional x-ray or fluoroscopy. The aim of this study was to measure the patient's entrance surface air kerma doses (ESAK) and dose area product (DAP).

The study conducted in three radiology departments: Omdurman military hospital, Omdurman friendship hospital and royal care international hospital. A total of 50 patients were studied from three hospitals; the exposure factors, the fluoroscopy time, number of radiographs taken and entrance surface dose were measured in a series of 50 consecutive patients undergoing HSG as part of their infertility work-up. Organ-dose values per radiograph and per minute of fluoroscopy were separately determined using the CalDose software.

The result of the study showed that the mean ESAK and DAP resulting from HSG were 2.18mGy and 66.48 Gycm2 respectively. The result of this study was higher compared with previous studies.The average HSG procedure involves a mean fluoroscopic time of (0.37) min and a mean number of radiographs of 3.2. The dose to female uterus and ovaries from an average HSG procedure were (2.78) and (2.92) mGy respectively, the patient effective dose was (1.2) mSv.

Radiation risks from a typical HSG are low, but they may be elevated if fluoroscopic and/or radiographic exposures are prolonged for any reason.

Present data allow the estimation of radiogenic risks associated with HSG procedures performed in other laboratories with use of different equipment, screening time and number of radiographs taken.

# المستخلص

تصوير الرحم (HSG) هو وسيلة فعالة لتقييم تشوهات الرحم وقناة فالوب باستخدام الأشعة السينية التقليديه أو التنظير. وكان الهدف من هذه الدراسة هو قياس جرعات سطح مدخل المريض (ESAK) وناتج الجرعة (DAP).الدراسة التي أجريت في ثلاثة أقسام للا شعة: المستشفى العسكري أم درمان ، مستشفى الصداقة أم درمان ومستشفى رويال كير الدولي. تمت دراسة ما مجموعه 50 مريضا من ثلاثة مستشفيات. تم قياس عوامل التعرض، ووقت التنظير، وعدد الصور الشعاعية التي اتخذت وجرعة سطح مدخل المريض في سلسلة من 50 مريضا على التوالي بالنسبه للمرضى الذين خضعو لتصوير الرحم HSG كجزء من متابعة العقم . وأظهرت نتائج الدراسة أن متوسط ESAK وDAP الناتجة عن HSG كانت mGy2.18 و66،48 mGy على التوالي. نتائج هذه الدراسة أعلى مقارنة مع الدراسات السابقه . معدل إجراء HSG يتضمن متوسط زمن تنظير مقداره (0.3) دقيقة ومتوسط عدد الصور الشعاعية 3.2. وكانت متوسط الجرعة للرحم والمبايض (2.78) (2.92) mGy على التوالي، وكانت الجرعة الفعالة للمرضى (1.2) ملي سيفرت.مخاطر الإشعاع من HSG منخفضة، ولكنها قد تكون مرتفعة إذا طالت التعرض لجهاز التنظير و / أو التصوير الشعاعي لأي سبب من الأسباب.

تسمح البيانات الحالية بتقدير المخاطر الإشعاعية المرتبطة بإجراءات HSG و اللتي أجريت في مختبرات أخرى باستخدام معدات مختلفة، ووقت فحص مختلف وياخد عدد من الصور الاشعاعيه .

# Chapter one

## 1.1 Introduction

Since it emergence in 1910, Hysterosalpingography (HSG) or Uterosalpingography became the most frequently used diagnostic tool to evaluate the endometrial cavity and fallopian tube by using conventional x-ray or fluoroscopy[Chalazonitis et al., 2009].Despite the development of the imaging tools such ascomputed tomography (CT), Magnetic resonance imaging (MRI), laparoscopy,hysteroscopy and ultrasound (US), HSG plays an extremely crucial role in the diagnostic, assessment and treatment of infertility in female patients [Úbeda et al,2001, Krysiewicz 2001].During the procedure, patients are subjected to fluoroscopic and radiographic exposures in genitourinary area; which is very sensitive to radiation, sinceit includes the ovaries and uterus. The partial exposure ofpatients result in aheterogeneous dose distribution; therefore the organ dose and effective dose values aremore appropriate descriptors of patient dose and related risks [Sulieman et al., 2008, Phillips et al., 2010, Plećaš et al., 2010] .

With the growing concern about radiation doses received by patients and cancer incidences over the years, there has been an emergent requirement for information on typical doses and the range of dose received during various radiographic and fluoroscopic examinations [Fife LA et al, 1994, Sharpton PC et al ,1986,Muhogora WE et al ,2008,Gyekye PK et al ,2009]. A pregnant patient has a right to know the magnitude and type of potential radiation effects that might result from *in utero* exposure. Fetal doses below 100 mGy should not be considered a reason for terminating a pregnancy due to prenatal death, malformation or impairment of mental development of the fetus[internatinal commission on radiological protection,2000].

Although this examination cannot be considered to be of a high risk level according to the expected values of its imparted collective dose, the requirements for radiation protection optimization are to be observed at an individual level because of the specificity of the patient-irradiated area and the high probability of pregnancy in the future. These facts stress the necessity of minimizing the possibility of the incidence of cancer due to radiation exposure.[fernandes et al,1996]

## 1.2 Problem of the study

During the HSG patients are exposed to fluoroscopic and radiographic exposure in genitourinary area (ovaries and uterus) ; which is very sensitive to radiation and one should consider the radiological risks associated with it for fetus and born child during the period of growth.

## 1.3 Objectives of the study

### 1.3.1 General objective

Estimation of radiation dose received by patients during hysteroslaingography(HSG).

### 1.3.2Specific objectives

-To measure the patients entrance surface air kerma (ESAK).

-To measure the dose area product (DAP).

-To measure ovaries and uterus dose.

-To find the correlation between ESAK and kVp, age.

-To find the correlation between DAP and kVp, age.

### 1.4. Overview of the Study:

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. 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. Chapter three describes the materials and a method used to measure dose and explains in details the methods used for dose calculation, Chapter fours deals with results.While Chapter five containsdiscussion, conclusion and recommendations.

# Chapter two

## Background and literature review

### 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, we discuss briefly the important 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 toward the target metal (anode). The generator also serves as an automatic control of the X-rays exposure and beam hardness by controlling the voltage which is applied between the lament and the target metal (Jaypee et al, 2011)

### 2.1.2 X-ray tube:

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

The cathode and the anode are the main components of the X-rays tube the cathode of the X-rays tube include 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 in tungsten. However rhenium molybdenum and graphite can also be used depending on the purpose of the specific tube. For example, for low energy mammography, molybdenum target is often used. The surface of the anode that impacted by the electrons beam is known as the focal spot. To reduce the heat capacity of the focal spot, rotational anode has been used in new X-rays devices. Modern X-rays tube s have tow filaments with current but gives low resolution, and a short filament which use high gives high resolution (jaypee et al,2001).

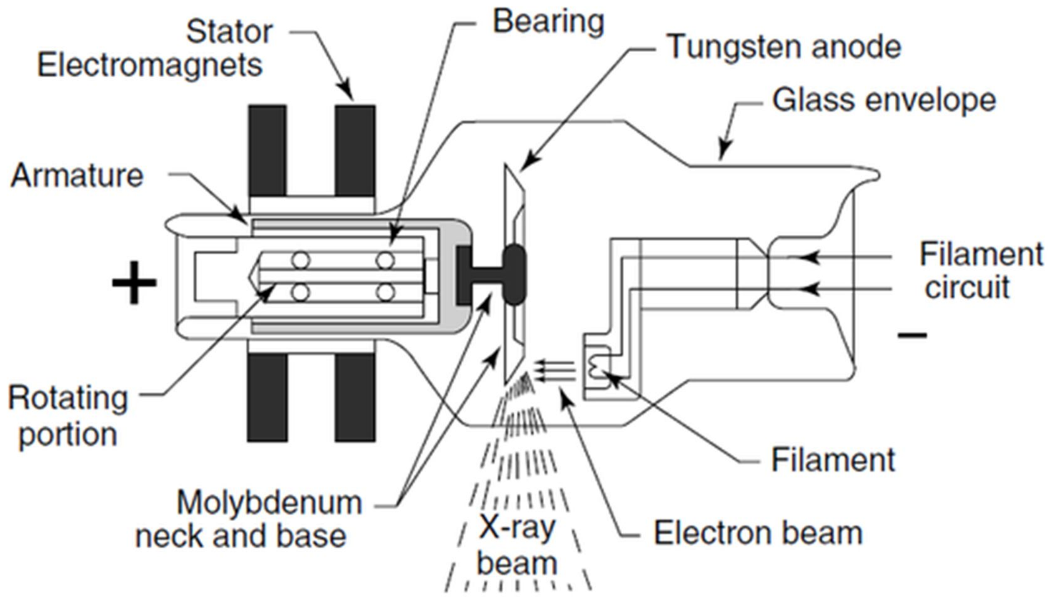
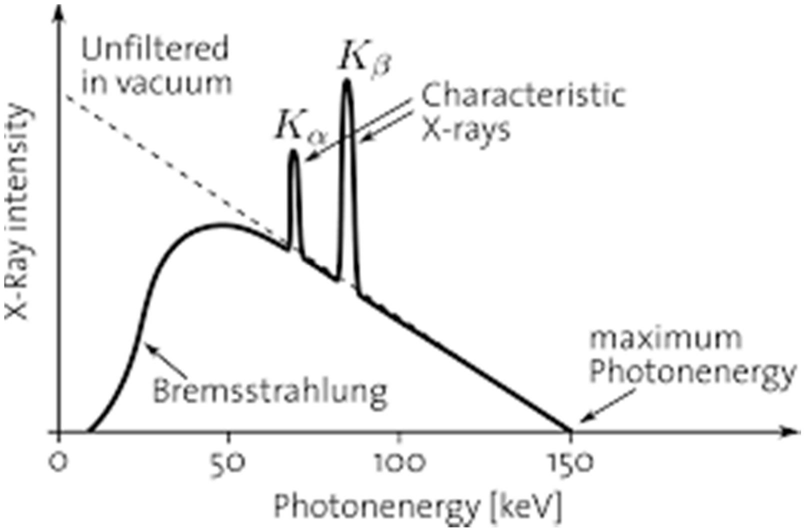


Figure (2.1) show the component of x-ray tube.

**2.2 X-rays beams**:

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



Figure( 2.2) show the x-ray beam.

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

## 2.3 Interaction of X-rays with matter:

X-rays interactions with matter are very important in diagnostic examination for many reasons. For example, the X-rays photographs are produced by particular interactions of X-rays with the structure of human body. As X-rays are photons, when an X-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 and matter. In this section we discuss briefly these interactions (James E. Martin, 2006).

### 2.3.1 Coherent scattering:

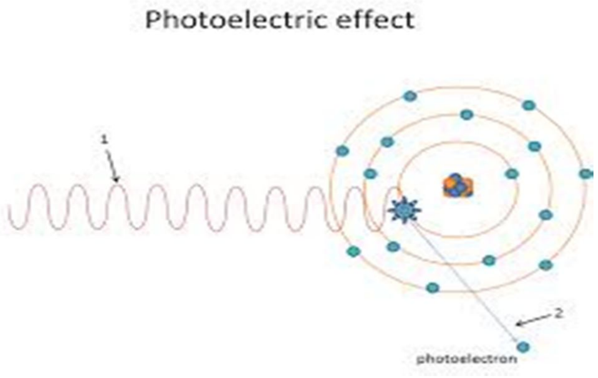
Coherent scattering, also known as classical scattering, occurs when a low energy X-ray photon interacts with the whole atom. The photon is scattered without change in the internal energy of both the interacting atom and the X-ray photon. Mainly this scattering happens in the forward direction. Although this type of interaction happens at low energy photons, it is generally not signification 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 e effect, also known as photo effect, take 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 this 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 part which is used to overcome the electron binding energy and the remaining energy is transferred to the electron as kinetic energy (James E. Martin , 2006), (Reilly Sutton, 1997).



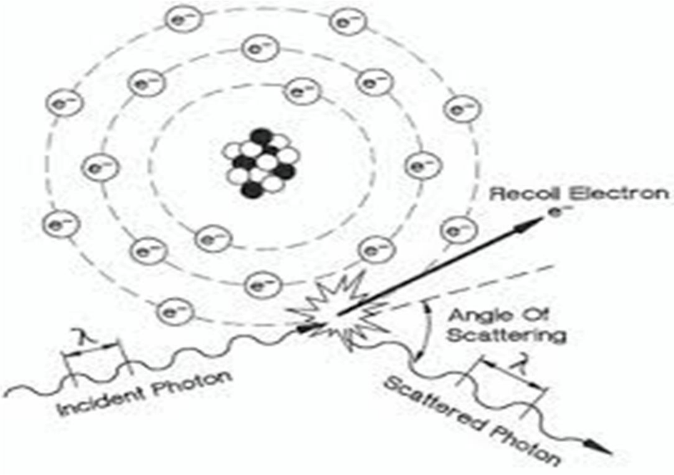
Figure(2.3) show the photoelectric effect.

### 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 outershell 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 $\lambda_c$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 $E_{eject}$ (Reilly Sutton,1997).



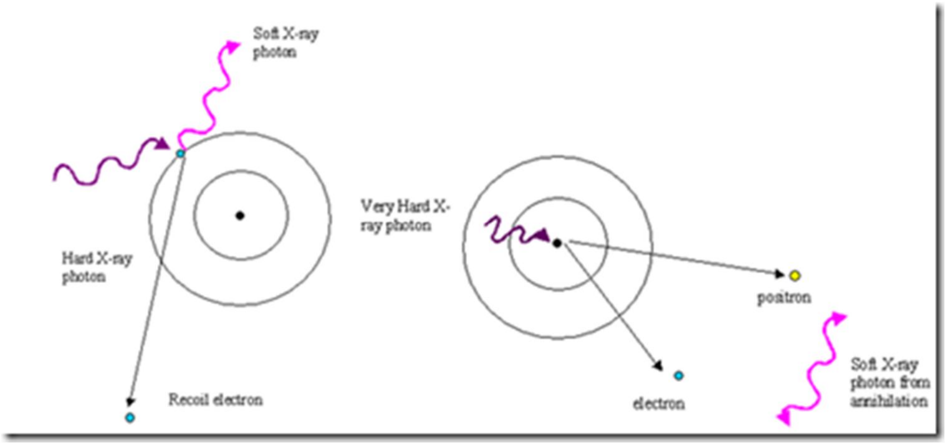
Figure(2.4) show the Compton scattering.

### 2.3.4 Pair production:

This interaction takes place when a high energy photon (>1.02$M_v$e) 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 equal t:

**$E_k$=hv-2$m_e c^2$:**

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 $2m_e c^2 = 1.02$ $M_e$V . This means that the probability for the pair production is zero for photon energies below the threshold and increases rapidly with photon energy above the threshold. Pair production is not encountered in diagnostic procedures due to its high energy threshold. However pair production is very useful for positron emission tomography (PET) in nuclear medicine (James E. Martin, 2006).



Figure(2.5) show the pair production.

### 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 in 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 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 Effect :

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

| 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 1 mSv | 1 in 25000 |

### 2.5 Radiation protraction method:

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

### 2.6 ALARA principle:

The ALARA Principle consists in maintaining the radiation dose as low as reasonably achievable taking into consideration economic and social constraints.

The goal of the ALARA Principle is to keep the radiation as far below the occupational dose limits, which is the annual dose limits to the workers within the ionizing radiation areas (50 mSv annual or 10 mSv age for accumulative)(Thomas E. Johnson et al, 2012). The ALARA Principle is based on the linear Non-threshold (LNT) dose effect 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 ofionizing radiation, no matter how  Small it is, has some detrimental effects associated with exposure (James E. Martin, 2006), (Epaoria, 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, a portion of the beam is either absorbed or scattered by the internal structure (soft tissue or bones). And the remaining X-ray beam which passes through the body is transmitted to a detector (e.g. a 1m or a computer screen). This transmitted part is very important in medical imaging as it forms the image (James E. Martin, 2006), (Reilly Sutton, 1997).

### 2.7.1. Radiography:

Radiography is an imaging technique that uses X-rays to view the internal structure of none uniformly composed and opaque object (a non –transparent object with a variation in density and composition) such as the human body. Radiographyis 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 monitor of the procedure or passage of a contrast agent (dye) through the body. This live X-ray view of the patient can be used to get real-time imaging and for aligning the patient to the X-ray tube for imaging (Jaypee et al, 2001). The main disadvantage of fluoroscopy is that it can result in relatively high radiation dose. Especially, in the case of complex intervention procedure e.g. during the operation to put some devices inside the body. However to reduce this disadvantages, the radiation dose modern system use image intensifiers and a closed circuit TV system (James E. Martin, 2006).

### 2.7.4. Other application of X-rays:

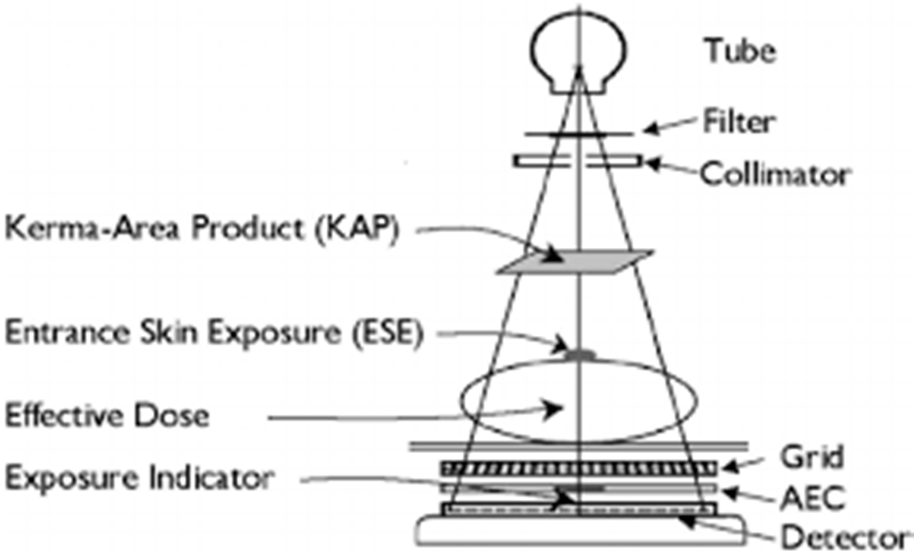
Apart from medical discipline, many other applications of X-rays exist. In industry, X-ray are used to detect flaws non-destructively in casting that are inaccessible to direct observation; this mechanism is called non destructive test X-rays microscope is capable of magnifying X-rays absorption images 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 ofimage 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 (IAEA, 2005).



Figure(2.6) show the radiation quantities.

### 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 (James, 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, 2006).

### 2.9.4. Entrance surface dose:

Entrance skin exposure is defined as the exposure in (R) at the skin surface of the patientexcluding 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, 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, 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 $2.58\text{x}10^4$ 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).

## 2.2 Previous studies

Sulieman A et al (2008) The study was attempt to measure patient and staff doses, estimate the effective dose and radiation risk for HSG using digital fluoroscopic images. Thirty-seven patients with infertility were examined using two digital X-ray machines. Thermoluminescence dosimeters (TLD) were used to measure entrance surface dose (ESD) for patients and staff during the procedure. The mean ESD and thyroid surface dose of the patient were 3.60 and 0.17 mGy, respectively, while the mean ESD for the staff was 0.18 mGy per procedure. The patient overall risk for cancer and hereditary effects is 24 x 10(-6), while the risk for the staff is negligible.

Prince K Gyekyeet al (2012),the aim of their study was to estimate cancer incidence of 120 patients undergoing hysterosalpingography (HSG) without screening at five rural hospitals and with screening using image intensifier-TV at an urban hospital. Free in air kerma measurements were taken for patient dosimetry. Using PCXMC version 1.5, organ and effective doses to patients were estimated. The effective dose to patients was estimated to be 0.20 ± 0.03 mSv and 0.06 ± 0.01 mSv for procedures with and without screening, respectively. The average number of exposures for both procedures, 2.5, and screening time of 48.1 s were recorded.

Khalid Alzimami et al(2014) they measured the patients' entrance surface air kerma doses(ESAK), effective doses and compared practices between different hospitals in Sudan. ESAK were measured for patient using calibrated thermo luminance dosimeters (TLDs, GR200A). Effective doses were estimated using National radiological Protection Board (NRPB) software. This study was conducted in five radiological departments: Two Teaching Hospitals (A& D), two private hospitals (B and C) and one University Hospital (E). The mean ESD was 20.1 mGy, 28.9 mGy, 13.6 mGy, 58.65 mGy, 35.7, 22.4 and 19.6 mGy for hospitals *A,B,C,D,* and *E),* respectively. The mean effective dose was 2.4 mSv, 3.5 mSv, 1.6 mSv, 7.1 mSv and 4.3 mSv in the same order. The study showed wide variations in the ESDs with three of the hospitals having values above the internationally reported values. Number of x-ray images, fluoroscopy time, operator skills x-ray machine type and clinical complexity of the procedures were shown to be major contributors to the variations reported. Results demonstrated the need for standardization of technique throughout the hospital.

Mohamed Yousef et al(2015)the aim of their study was to determine and evaluate the radiation dose for females under going HSG during the reproductive period, the study was conducted in three radiology departments;Omdurman teaching hospital, AlneelianDiagnostic Center and Asia Specialized Hospital . A total of 50 patients was studied from three hospitals,20 patients from NeelainDignostic Center in range of (25-40)years, 20 patients from Omdurman Teaching Hospita in range from (24 to 43)years. patient dose measurements was performed using unfors dosimeter. Organ dose and effective dose were estimated using National Radiological Ptotection Board Software. The result was showing that; the mean patient dose was 20.1 and 28.9 and 13.6 Omdurman Teaching Hospital, NeelainDignostic Center and Asia Specialized Hospital, respectively. Ovaries and uterus have the highest dose compared to other organ.

# Chapter three

# Materials and methods

## 3.1 Materials

### 3.1.1 Subjects:

A total of 50 patients aged (18-43) were examined for a period of 4 months in three radiological departments.

### 3.1.2. Machine used:

Table 1: x-ray machine technical data

| Hospitals | Type | Filtration mm AL | Maximum tube voltage(kVp) | Date of installation |
|---|---|---|---|---|
| A | Toshiba | 2 | 150 | 2011 |
| B | Toshiba | 2.5 | 100 | 2010 |
| C | Dong Fang | 3.2 | 120 | 1996 |

## 3.2 Method:

### 3.2.1 Image technique

At the beginning of the procedure patient lies supine on the table in lithotomic position bends her knees and places her feet at the end of the table. A vaginal speculum is inserted into the vagina; the vaginal walls and cervix are cleaned with antiseptic solution. A cannula is inserted into cervical canal attached with syringe filled with contrast medium (CM). After injecting the CM, a minimum of four films are obtained during conventional radiography by using 10x12 inch films with vertical center rays 5cm superior to the symphysis pubis. This includes the following: an AP plain radiograph, 2 AP film with CM to show the uterus, an AP film with CM to show the uterine tubes, an AP film with CM to show spill of CM in the peritoneal cavity. The technologists perform the investigations as their daily practice. Demographic data: (age, height, weight and body mass index (BMI (kg/m2) and exposure factors: (kVp and tubecurrent-time product (mAs)) are obtained for all patients.

### 3.2.2 Entrance surface air kerma estimation

Free in air measurements with RAD-CHECK PLUS (CE Invasion, Nuclear Associates Div. of Victoreen, Inc.) placed at 100 cm from the X-ray tube were made, varying tube voltage (kV) and current-time product (mAs). The output ratio (mGy/mAs) is plotted against kV to obtain an ESAK curve. This procedure was repeated for all the three hospitals considered for the study.

From the curve, the output ratio (mGy/mAs) can be extrapolated with a known kV. The ESAK is estimated using equation 1 with a known focus to skin distance (FSD) and mAs per examination.

### 3.2.3 Dose area product estimation

Dose Area Product (DAP) on the surface of the patient was estimated using the equation below with a known X-ray field area (A) at the focus-to-film distance (FFD), FSD and the estimated ESAK. In the absence of appropriate equipment, the mathematical relationship between DAP and ESD or ESAK may be used [Yakoumakieset al, 2001].

$$DAP = ESAK\ x\ A_{FFD}\ x\ \left(\frac{FSD}{FFD}\right)^2 \qquad .....(2)$$

# Chapter 4

## 4.1 Results:

This study intended to provide an evaluation of radiation dose during HSG and to analyze factors that might affect the radiation dose for patients. Patient body characteristics data (age, weight and length) are represented in (Table 2).

Table 4.1: patient body characteristic (age, weight and length).

| | **Age** | **Weight** | **length** |
|---|---|---|---|
| Mean | 29.68 | 67.00 | 161.42 |
| Median | 30.00 | 65.00 | 160.00 |
| Std.Deviation | 7.314 | 9.459 | 8.09 |
| Minimum | 17 | 50 | 140 |
| Maximum | 43 | 90 | 177 |

Table 4.2: the exposure factors (kV and mAs)

| | **kV** | **mAs** |
|---|---|---|
| Mean | 86.82 | 43.80 |
| Median | 94.50 | 32.00 |
| St.Deviation | 13.074 | 14.879 |
| Minimum | 60 | 32 |
| Maximum | 100 | 75 |

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Table 4.3: The ESAK ,DAP,Ovarian dose and Uterus dose to patients undergoing HSG

| | ESAK | DAP | Ovarian dose | Uterus dose |
|---|---|---|---|---|
| Mean | 2.254 | 66.48 | 2.78 | 2.92 |
| Median | 2.152 | 65.60 | 1.67 | 1.87 |
| St. Deviation | 0.372 | 3.71 | 0.23 | 0.45 |
| Minimum | 1.576 | 57.66 | 1.85 | 2.03 |
| Maximum | 3.955 | 71.19 | 3.2 | 3.85 |

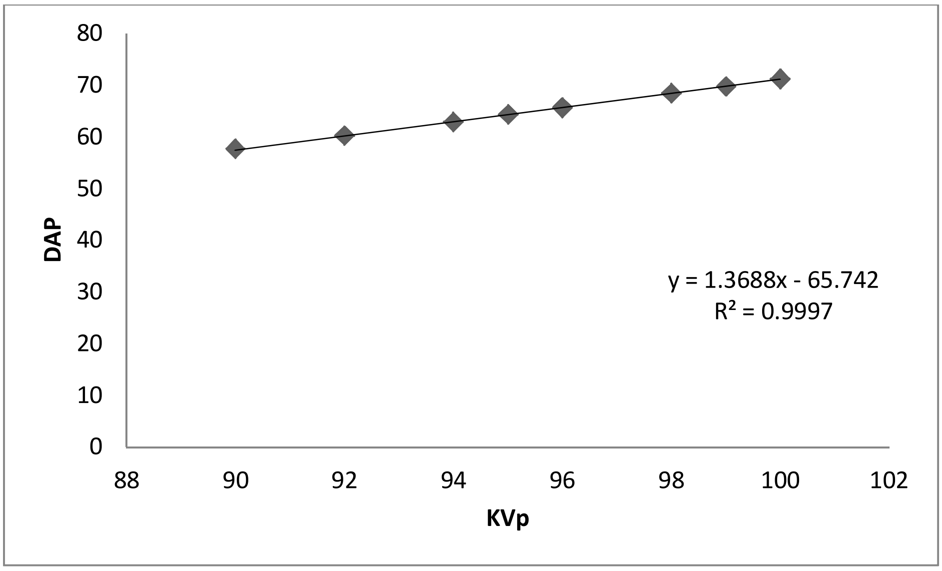

Figure 4.1: the correlation between dose area product (DAP) and kilovoltage (kVp) for patients undergoing HSG procedure.

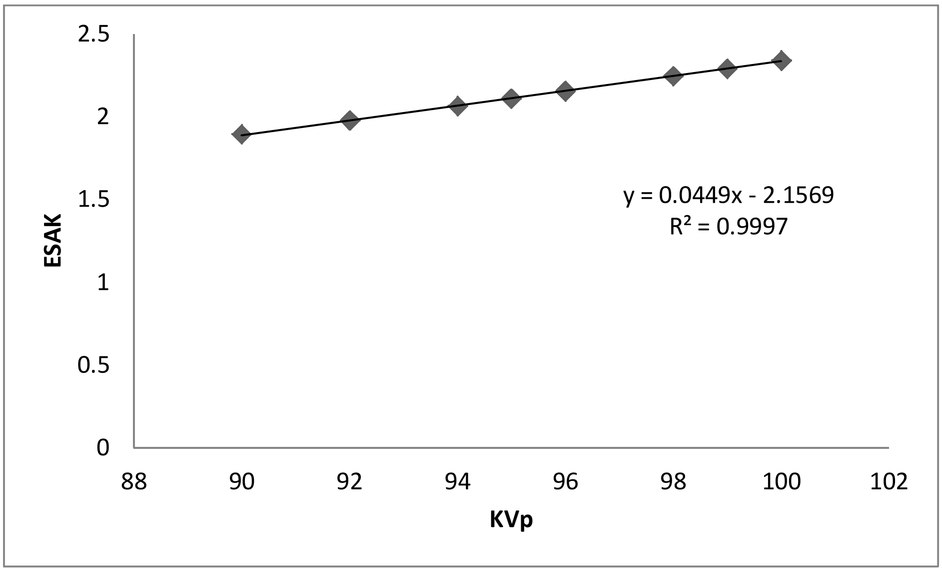

Figure 4.2: the correlation between entrance surface air kerma (ESAK) and kilovoltage (kVp) for patients undergoing HSG procedure.

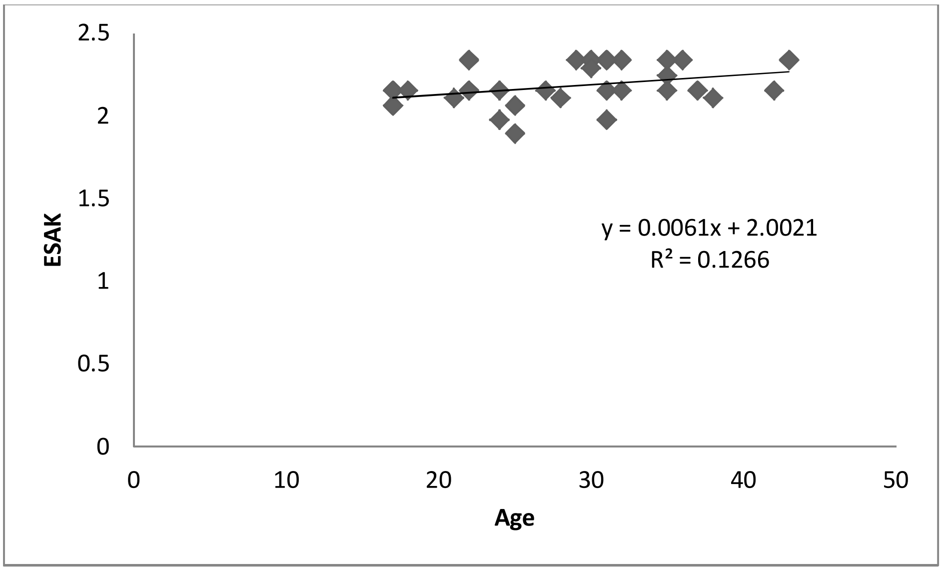

Figure 4.3: the correlation between entrance surface air kerma (ESAK) and Age for patients undergoing HSG procedure.

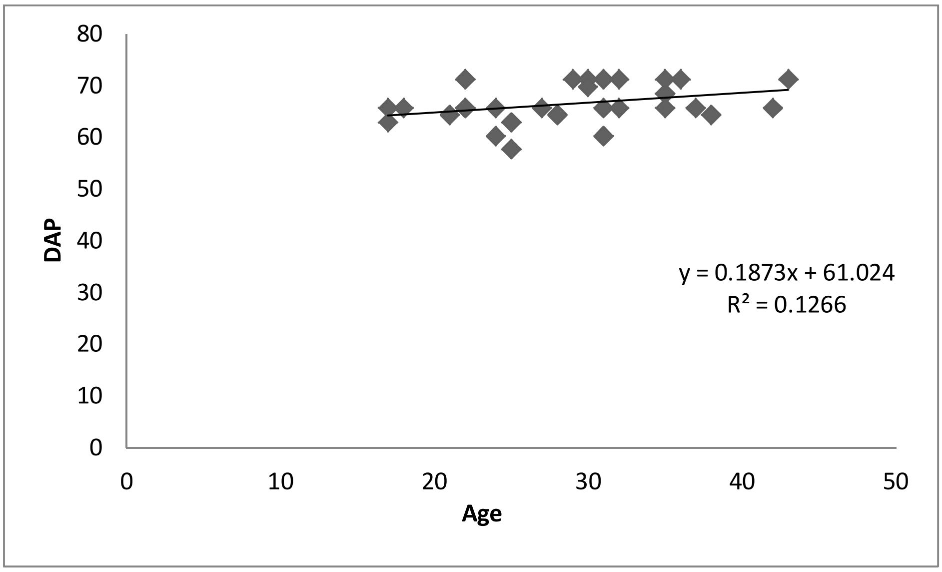

Figure 4.4: the correlation between dose area product (DAP) and Age for patients undergoing HSG procedure.

# Chapter 5

# Discussion, Conclusion and Recommendation

## 5.1 Discussion:

In this study, The mean patient's age, height and weight were 29.68 years,1.61m and 67.00kg respectively. The mean number of radiographs used is 3.2. The exposure factors (kV, mAs) are presented in (Table 3). In general, high kVp increase the scatter radiation thus also the patient's dose, while decreasing the contrast of the image. The quality of the radiation depends on the tube voltage and the total filtration of the X-ray beam.

Radiographic exposure factors used in this study ranged 60-100kVp and 60-32 mAs (the highest kVp used is 100 kVp and the lowest kVp used is 60 kVp, the highest mAs used is 60 mAs and the lowest mAs used is 32.00 mAs).The ESAK ,DAP,ovarian dose and uterus dose to patients undergoing HSG are illustrated in (Table 4).

The mean ESAK and DAP resulting from HSG procedure has been estimated to be 2.18 mGy and 66.48 Gycm, respectively. The mean ESAK result is higher than the previous study (Prince K et al 1.33 mGy). This result indicates that a low degree of patient dose achieved in the previous studies.The mean ovarian dose and uterus dose was estimated as 2.78 mGy and 2.92 mGy respectively. Figure (4.1, 4.2) shows that there was correlation found between ESAK values, DAP values and kVp (correlation coefficient R2=0.999). Figure (4.3) shows that there is adirect linear relationship between ESAK and Age where ESAK increase by 0.006mGy/year. Figure (4.4) shows that there is adirect linear relationship between DAP and Age where DAP increase by 0.19mGycm2/year.

## 5.2 Conclusion:

This study measured the patient doses during HSG in three hospitals in khartoum state, the mean ESAK result in this study is higher than the previous studies. The dose values showed wide variation in three hospitals.This can be attributed to the machine chracteristics,technique and operator experiances.Optimization technique is important in order to reduce patient doses to the international levels.

## 5.3 Recommendation

X-rays Radiography operator should be optimized; this is 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.

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