CHAPTER ONE

INTRODUCTION

1-1: Introduction:

Staff dose arising from the use x-rays are principally due to scattered radiation. This is related to the dose received by the patient expressed as the dose area product (DAP). Does to patients in interventional radiology are generally higher than for other fluoroscopically guided procedures. Doses to interventional radiologist are, therefore, amongst the highest associated with use of diagnostic x-rays. The results of staff dose monitoring normalized to (DAP) should provide an indicator of those procedures which are associated with particularly high radiation exposures to staff, and should help to identify those radiologists whose practice may result in unnecessarily high dose to themselves (J. Rilliams 1997).

The wider use of medical imaging involving x-rays during interventional procedures has led to steadily increase the exposure of the medical staff to ionizing radiations. The expansion of interventional cardiology procedures in recent years makes it a specialty with a high potential for exposure and interventional cardiologists may present a risk of radiation induced effects at eye level, an area often neglected in the radiation protection of operators (Sophic 2010). Dosimetry studies in the operators of interventional medicine including cardiology have shown that a potential risk to the eye could exist (F.R.A.lima et al). The risk potential assessment is the first step in the gateway process. It provides a standard set of high level criteria for assessing the degree of complexity of a proposed acquisition based programme project (B.Fwall et al 1997).

Interventional cardiologists are at greater risk from radiation exposure as a result of the procedures they undertake than most other medical specialists.

Interventional cardiology is recognized as a high radiation risk practice and evaluation and follow up of occupational doses should be considered an important part of quality assurance programmes. Cardiovascular interventional therapy is effective therapeutically for different diseases (C. Foti,K 2008).

Cardiac interventional procedures can be complex and involve the extensive use of relatively low dose rate from fluoroscopy and relatively high dose rate sequence of image acquisitions. The staff operate near patient and exposed to anon uniform radiation field due to patient scattered radiation consequently worker may receive over a period relatively doses (Sorrjarod et al 2007).

Medical hospital it is remarkable that an increasing number of interventional procedures are being performed using x-ray equipment to guide interventions in the body but till new typical doses encountered during these examinations are not exactly known. The present study project was initiated with the aim of evaluating the radiation doses to patient undergoing interventional (IR، IC) in Sudan's hospital and the result will be compared with interventional reference dose levels.

1-2: History of X- Rays

In the latter half of the year 1895, a German scientist called Roentgen was working in his laboratory at the physical institute of the University of Wurzurg German, experimenting with a type of discharge tube called crook's tube, but is not clear exactly which aspects of cathode rays he intended to study. The tube displayed fluorescent glow when a high voltage current was passed through it. When he shielded the tube with heavy black cardboard he found that a greenish fluorescent light could be seen on fluorescent screen kept some 9 feet away.

Roentgen concluded that a new type of ray was emitted from the tube that could pass through the black covering. The rays could pass through most substances, including the soft tissues of the body, but left the bones and most metals visible. One of his earliest photographic plates from his experiments was that of a film of his wife, Berthas hand with airing. Roentgen named invisible radiation as X-rays or unknown rays(Herman et all 2009).

1-3: Catheterization Procedures:

In the catheterization laboratory, the insertion areas are cleansed with a sterilizing solution, shave and cornered with sterile drapes. A small needle injection of a local anesthetic is used to numb area. A small incision is made and a pencil sized

Plastic tube, called a sheath is inserted in to the artery. A catheter, which usually 2 to3 mm in diameter, is passed via the sheath the artery to the heart, and into a coronary artery.

A contrast agent (dye) is injected in to the catheter to show areas of blockage and angiograms of the artery are taken. The dye often causes sensation throughout the body that last 10 to 15 seconds. In some cases a catheter is passed through the sheath to the heart left ventricle and dye injected to show the left ventricle is functioning.

1-4: Interventional Cardiology

For interventional examinations the tube orientation will depend on the location of the vessel that needs to be treated. In this case only a few orientations are selected and the number of acquisition runs will depend on the nature and complexity of the treatment. It is these types of procedures that present the greatest risk to the patient of deterministic effects (Rasha M. 2011).

Cardiac catheterization is a procedures used to determine if there is a problem. Once a problem is identified then treatment is required which can be in the form of angioplasty, coronary stents or cardiac surgery where possibly a graft is required. In angioplasty a deflated balloon is inserted into narrowed coronary arteries and then inflated in order to widen it. The balloon is removed once the widening has been completed. And it open. These types of interventional techniques are more complex and can require more extensive imaging. As only one area of the treat may be treated the x-ray beam may be orientated toward same area of the patient's skin for longer periods of time and has an increased likelihood of developing skin damage (Royal College 2012).

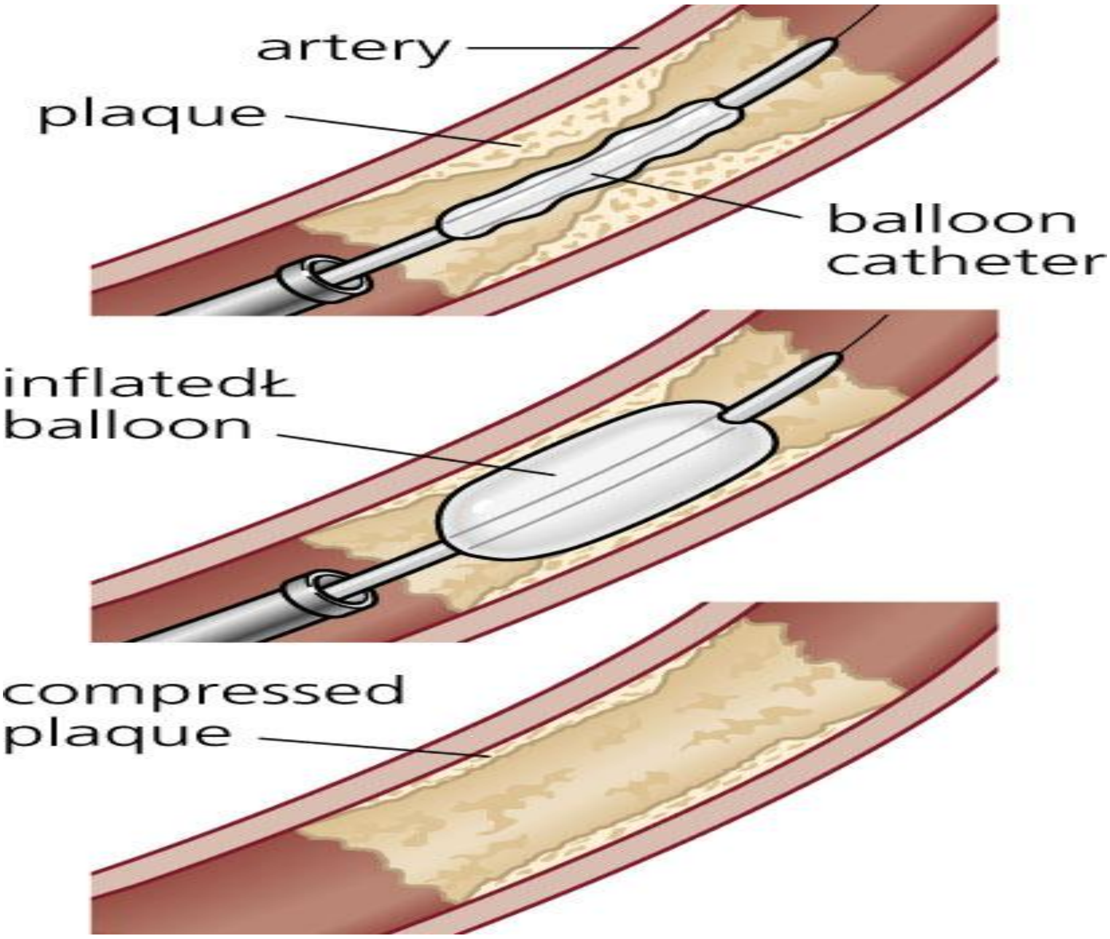


Figure1-1: Insertion of a balloon catheter

1-4-1: Interventional Cardiology procedures can include to:

- Balloon Angioplasty creates a space in a blocked artery by inserting and inflating a tiny balloon. The balloon compresses the plaque against the wall of the artery so blood can flow more freely. The balloon does not remain in the body.

- Carotid Stents and Stroke Intervention involves the insertion of a stent to expand the carotid arteries located on each side of the neck, extending from the aorta to the base of the skull to supply blood to the brain. If a clot or plaque blocks the blood flow to the brain, it can cause a stroke, resulting in brain damage or death. Congenital Heart Defect Correction can be employed to correct trial septal and ventricular septal defects, closure of a patent ducts arteriosus and angioplasty of the great vessels.

- Fractional Flow Reserve (FFR) can accurately measure blood pressure and flow through a specific part of the coronary artery. The measurement of FFR has been shown useful in assessing whether or not to perform angioplasty or stinting on intermediate blockages.

- Intracoronary Stinting requires the permanent insertion of a tiny stainless steel wire-mesh tube called a stent to keep arteries open following a balloon angioplasty. Both bare-metal and drug-eluting (medication-releasing) stents are available.

- Intravascular Ultrasound involves a small catheter in the coronary artery to emit sound waves that produce an image of the blockage, providing the cardiologist with needed information to best manage the blockage.

-Implantable Cardioverter Defibrillators (ICDs) help treat patients at high risk for sudden cardiac arrest. Implanted through a small incision near the shoulder, ICDs use electrical pulses or shocks to help control life-threatening and irregular heartbeats.

- Pacemaker Insertion is for patients with abnormally slow heart rhythms, congestive heart failure and those at risk for sudden death. Pacemakers help coordinate the pumping action of the heart by sending electrical signals, allowing the heart to pump more effectively (F.Bouzarjomehri et all 2009).

1-5: C-Arm Machine

C- Arms are one of the driving technological forces behind the advancement of minimally invasive surgeries. These mobile fluoroscopic imaging systems are précis and accurate devasive allow for less patient discomfort in a variety of surgical and nonsurgical procedures. The minimal invasiveness with the use of c-arm has helped lead to the increase of more cost- effective outpatient care. C-Arms provide patients with minimally invasive, pain reduced procedures. Initially used surgery or orthopedic applications, c- arms are now described by both manufactures and users as highly versatile, thanks to technological advancements made since the original designs. In fact, c-arm usage recently has expanded to in clued minimally invasive spinal general and orthopedic surgeries, pain management, and cardiac, urology, and neurovascular applications(Raphael et all 2004).

1-5-1: C- Arm X-ray Machine Used for.

Many advances in medical technology have helped make procedures less invasive and more comfortable for patients. The C-Arm device which was introduced by c-arm slays Philips in 1955.Isone exams of this advancement and enables and patients to see result is less time.

1-5-2: Design:

C-Arm is a one given to specialized x-ray imaging machines, due to their special arced semi- circular design. C- Arm use x- rays for imaging, but are designed to work with lower amount of exposure.

1-5-3: Advantages:

C- Arm x-ray machines use intensifiers that magnify readings. This allows lower amount of the x- ray to be used, and results in less radiation exposure for patient and professionals**.**

1-5-4: Applications:

C- Arm machines are often smaller than traditional units, and can be used in more confined spaces. This means that x- ray exposure can be fine tuned, and results in lower radiation levels.

Figure 1-2: C- Arm machine

1-6: Radiation Risk to Interventional Cardiology:

Cardiac interventional procedures can be complex and involve the extensive use of relatively low dose rate from fluoroscopy and relatively high dose rate from sequence of image acquisitions. Therefore it can produce skin injuries as typical deterministic effects, resulting from high radiation doses imparted to some areas of the patient's skin the factor of that patient size which is the main reasons for large doses to the skin. Pacific the risks medical personnel are often underestimated due to the small amount of acute radiation exposure form each examination. However for cardiologists with a high workload, the total exposure may lead to a significant cumulative dose and radiation risk. Additionally, cardiologists are exposed to scattered radiation which results in non uniform dose rates. Cardiologists receive high doses to hand and extremities that may be unshielded, and which may increase the cumulative risk. Further move ionizing radiation is also carcinogen radiation induced cancers do not appear immediately after radiation exposure but require time the latent period, to become clinically apparent.

It is widely recognized that some procedures in Interventional cardiology (IC) carry greater radiation risks than many other radiological examinations. There are increased stochastic risks to the patient from long Screening procedures and a greater risk of deterministic effects, generally to the skin, especially when the radiation beam is directed at the same area on the skin surface for most, if not all, of the examination. There are also increased stochastic risks, and possibly deterministic risks, to staff that are close to the patient from scattered radiation. For all of these reasons, the European Council. Directive of 30 June 1997 on ‘‘Health protection of individuals against the dangers of ionizing radiation to medical exposure, and repealing Directive 84/466 Euratom’’ identified IC as a ‘‘Special Practice’’ requiring special attention to be given to quality assurance programmes, quality control measures and patient dose assessment. Several publications give information and/or guidance on radiological protection in IC. However, in the past 4 years, the number, diversity and complexity of IC examinations have all increased markedly. Therefore, it is timely to review recent progress, current problems and plans for the future. British Institute of Radiology on 28 March 2007 to address these issues. The multidisciplinary nature of many of them was emphasized(Eleni et all 2012).

1-7: Objectives:

The current study intends to:

- Measured the patients and staff doses interventional cardiology with emphasis in interventional cardiac catheterization procedures.
- Calculate organ and effective dose to the staff
- Assessment the organs and effective doses to the staff.
- Estimate the cancer risks from the cardiac procedures.
- Optimize patient and staff doses during cardiac catheterization procedure.
- Propose national diagnostic reference level in Sudan.

1-8: Problems of the study:

Interventional cardiologists in valves diagnostic and therapeutic procedures are becoming increasing common and therapeutic procedures are often treatment of choice, resulting in increasing lengthy and complex techniques. Thus patients are being exposed to highly localized x- ray sources for extended periods of time long enough to cause possible skin injuries.

The fluoroscopic examination done in our national medical centers may give high dose to patients and staff which in term may lead to radiation diseases in future.

Radiation dose measurement is important in order to estimate the possible risks from diagnostic and therapeutic procedures. Interventional procedures are one of the most common procedures due to their numerous indications. During these procedures patients and staff are exposed frequently to radiation and many x-rays are obtained.

Patients and staff dose during cardiologic procedures is considered to be high due to the existences of the operators beside the patient, while x- ray procedures is undergoing, and the prolonged exposure time to the patient. Since there is no enough assessments were made at the national level to estimate the significance of the radiation doses to the patient and staff, thus radiation dose measurements are required.

1-9: Thesis Outline:

This thesis is divided in to five chapters as follows:

Chapter one is gives a general introduction of x- ray radiation (interventional cardiology and radiology, catheterization), radiation to patient and staff and objective of study.

Chapter two is devoted to the general information about x-ray, radiation quantities and units, dose instrumentations, literature review to the previous local and international studies, techniques of measurement interventional cardiology procedures.

Chapter three material and techniques of interventional cardiology examinations are presented in the chapter and describe the calculation and method of effective dose edition.

Chapter four presents the results of the study to data collection

Chapter five gives discusses the finding result of the study, conclusions about interventional procedures and brief recommendations for future studies.

1-10: Thesis outcome:

The following papers were published during this study:

1-Abdelrahman A. Ahmed, Mohamed E.M.Gar-elnabi, Abdoelrahman Hassan, Mohamed Yousef- Evaluation of Radiation Dose Received By Patient during Cardiac Catheterization Procedure. International Journal of Science and Research (I.JSR) - Volume 4 Issue 3, March 2015.

2- Abdelrahman A. Ahmed, Mohamed E.M.Gar-elnabi, Abdoelrahman Hassan – Evaluation of Radiation Dose for Cardiac Catheterization Staff. International Journal of Science and Research (I.JSR)- Volume 4 Issue 3, March 2015.

CHAPTER TWO

THEOTICAL BACKGROUND and LITERATURE PREVIEW

2-1: Discovery of X- rays:

In late 1895, a German physicist, W. C. Roentgen was working with a cathode ray tube in his laboratory. He was working with tubes similar to our fluorescent light bulbs. He evacuated the tube of all air, filled it with a special gas, and passed a high electric voltage through it. When he did this, the tube would produce a fluorescent glow. Roentgen shielded the tube with heavy black paper, and found that a green colored fluorescent light could be seen coming from a screen setting a few feet away from the tube. He realized that he had produced a previously unknown "invisible light," or ray, that was being emitted from the tube; a ray that was capable of passing through the heavy paper covering the tube. Through additional experiments, he also found that the new ray would pass through most substances casting shadows of solid objects on pieces of film. He named the new ray X-ray, because in mathematics "X" is used to indicated the unknown quantity.

In his discovery Roentgen found that the X-ray would pass through the tissue of humans leaving the bones and metals visible. One of Roentgen’s first experiments late in 1895 was a film of his wife Bertha's hand with a ring on her finger (shown below on right). The news of Roentgen’s discovery spread quickly throughout the world. Scientists everywhere could duplicate his experiment because the cathode tube was very well known during this period. In early 1896, X-rays were being utilized clinically in the United States for such things as bone fractures and gunshot wounds(Herman et all 2009).

2-2: Production of X- ray

There are two different atomic processes that can produce X-ray photons. One process produces Bremsstrahlung radiation and the other produces K-shell or characteristic emission. Both processes involve a change in the energy state of electrons. X-rays are generated when an electron is accelerated and then made to rapidly decelerate, usually due to interaction with other atomic particles.

In an X-ray system, a large amount of electric current is passed through a tungsten filament, which heats the filament to several thousand degrees centigrade to create a source of free electrons. A large electrical potential is established between the filament (the cathode) and a target (the anode). The cathode and anode are enclosed in a vacuum tube to prevent the filament from burning up and to prevent arcing between the cathode and anode. The electrical potential between the cathode and the anode pulls electrons from the cathode and accelerates them as they are attracted towards the anode or target, which is usually made of tungsten. X-rays are generated when free electrons give up some of their energy when they interact with the electrons or nucleus of an atom. The interaction of the electrons in the target results in the emission of a continuous Bremsstrahlung spectrum and also characteristic X-rays from the target material.

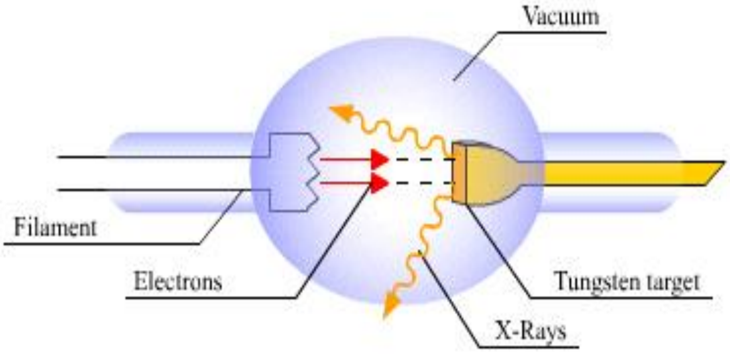


Fig- 2-1 X- ray Tube

2-3: Classification of Radiation:

2-3-1: Definition:

Radiation is energy in transit in the form of high speed particles and electromagnetic waves. We encounter electromagnetic waves every day. They make up our visible light, radio and television waves, ultra violet, and microwaves and are part of a large spectrum of energies. Radiation classification to:

2-3-1-1: Ionizing Radiation:

Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from their orbits, causing the atom become charged or ionized. Examples are gamma rays and neutrons.

2-3-1-2: Non- ionizing Radiation:

Non- ionizing radiation is radiation without enough energy to remove tightly bound electrons from their around atoms. Examples are microwaves and visible light.

2-3-2: Radioactivity:

Radioactivity is the spontaneous transformation of an unstable atom and often results in the emission. This process is referred to as a transformation, decay or a disintegration of an atom. Radioactive material is any material that contains radioactive atoms. Unstable atoms are said to be radioactive. In order to reach stability, these atoms give off, or emit, the excess energy or mass. These emissions are called radiation. The kinds of radiation are electromagnetic and particulate. Gamma radiation and x rays are examples of electromagnetic radiation. Gamma radiation originates in the nucleus while x rays come from the electronic part of the atom. Beta and alpha radiation are individual monolithic detector elements examples of particulate radiation(IAEA 2001).

2-4: Radiation Quantities:

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

Table 2-1 Radiation Quantities (Verdun Francis et al 2011)

Radiation concentration	Total Radiation
Photon Fluence	Total Photons
Energy Fluence	Total Energy
Exposure	Integral Exposure
Dose	Integral Dose
Dose Equivalent	-

2-4-1: Exposure:

Exposure is a radiation quantity that expresses the concentration of radiation delivered to a specific point, such as the surface the human body. There two units for expressing exposure. The conventional unit is roentgen(**R**) and the **SI** unit is coulomb per kilogram of air (**C/Kg**). The roentgen is officially defined in terms of amount of ionizing produced in a specific quantity of air. The ionizing process produces an electrical change that is expressed in the unit of coulombs. So by measuring the amount of ionizing in coulombs in a known quantity of air the exposure in roentgen can be determined **(**Verdun Francis et al 2011**)**.

2-4-2: 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 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 deposed in or absorbed in unit mass (Kg) of air. Therefore, the quantity kerma is expressed in the unit of (J/Kg) which is also the radiation unit the gray (Gy).

2-4-3: Absorbed Dose:

Absorbed dose is the radiation quantity used to express the concentration of radiation energy actually absorbed in a specific tissue. This is the quantity that is most directly related to biological effects. Dose values can be in the traditional unit of the rad of 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(Nazar2012).

2-4-4: Entrance Surface Dose (ESD):

Entrance surface dose is defined as the exposure in roentgens at the skin surface of the patient without the backscatter contribution from the patient. This measurement is popular because entrance skin exposure is easy to measure, but unfortunately the entrance skin exposure is poorly suited for specifying the radiation received by patient undergoing radiographic examination. The entrance skin exposure does not take into account the radio sensitivity of individual organs or tissue, the area of an x-ray beam, or beams penetrating power, therefore, entrance skin exposure is poor indicator of the total energy imparted to the patient.

The (ESD) is related to the incident absorbed dose, ID by the backscatter factor BSF: ESD = ID* BSF

The BSF depends on the x-ray spectrum, the field size, thickness of the patient and distance between the effective centre of the dose measurement patient and the surface. The flounce of the latter factor can be minimized by using dosimeter of small volume directly attached to the patient skin (Herman et al 2008).

2-4-5: Dose Area Product (DAP):

Dose area product (DAP) is defined as the absorbed dose to air or the kerma averaged over the area of the x-ray beam in a plane perpendicular to the beam axis, multiplied by the area of the beam in the same plane. The Gy-cm^2 is the referred unit for DAP. The quantity is also referred as kerma area product.

2-4-6: Equivalent Dose:

In radiological protection, it is the absorbed dose averaged over a tissue or organ and weighted for the radiation quality that is of interest (ICRP1991). The weighting factor this purposes is called the radiation weighting factor W_R, and is selected for the type and energy of the radiation incident on emitted by the source.

2-4-7: Effective Dose:

The international commission radiation protection (ICRP), along with other entities concerned with radiation protection, has introduced the concept of dose equivalent in order to discriminate between different types of radiations. The equivalent dose defined as the absorbed dose multiplied by dimensionless factor Q. Q known as the quality factor, is based on the biological effectiveness of different kind of radiation, which in turn depends on the linear energy transfer (LET) of that particular radiation. LET is defined by the ICRP as the unrestricted. To account for the differing radio sensitivities of different tissues, the ICRP firth her introduced the concept of effective dose. Along with the quality factor Q, the absorbed dose is multiplied by a tissue weighting factor (W_T) specific to the organ of interest. Since the sum of the ICRP tissue weighting factors is unity, each individual weighted organ dose can be summed to obtain an effective dose that represent the risk for all stochastic effects to an irradiated individual(badreldin 2012).

Table 2-2 Tissue weighting factors for different organs (UNSEAR 2008)

Organs	Tissue weighting factors		
	ICRP30(1979)	ICRP60(1990)	ICRP103(2007)
Gonads	0.25	0.20	0.08
Clon	-	0.12	0.12
Lung	0.12	0.12	0.12
Red bone marrow	0.12	0.12	0.12
Stomach	-	0.12	0.12
Bladder	-	0.05	0.04
Breast	0.15	0.05	0.12
Liver	-	0.05	0.04
Esophagus	-	0.05	0.04
Thyroid	0.03	0.05	0.04
Bone surface	0.03	0.01	0.01
Skin	-	0.01	0.01
Brain	-	-	0.01
Salivary	-	-	0.01
Remainder	0.03	0.05	0.01

Table 2-3: Radiation weighting factors in publication 60 and Q in pulication 26

Type and energy range	W_T	Q
Photons (x-ray and gamma rays) all energies	1	1
Electron, muons, all energies	1	1
Neutrons < 10 Kev	5	-
Neutrons 10 kev to 100 kev	10	-
Neutrons > 100 Kev to 2Mev	20	-
Neutrons > 2 Mev to 20 Mev	10	-
Neutrons > 20 Mev	5	-
Protons > 20 Mev	5	1
Alpha particles fission- fragmens heavy nuclei	20	20

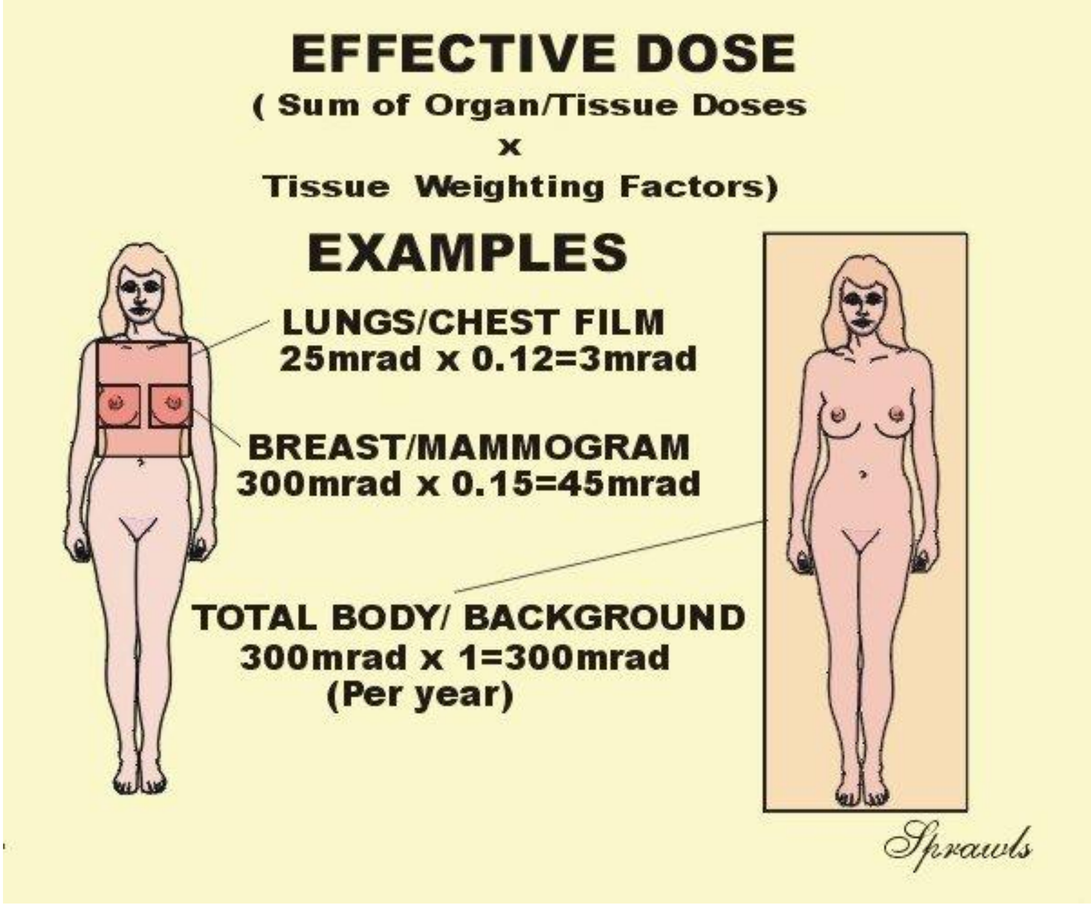


Figure 2- 2: The concept of effective dose (RICP 2012)

2-5: Radiation Units:

2-5-1: Roentgen(R):

The roentgen is a unit used to measure a quantity called exposure. This can only be used describe, an amount of the gamma, x-ray and only in air. One roentgen is equal to depositing in dry air enough energy to cause $2.58x10^{-4}$ coulomb per kilogram (R= $2.58x10^{-4}$ c/kg), It is a measure of the ionizations of the molecules in a mass of air. The main advantage of this unit is that too easy to measure directly, but it is limited because it is only for deposition in air, and only for gamma and x- rays (IAEA2004).

2-5-2: Rad (rad):

The rad is a unit used to measure a quantity called absorbed dose. This related to the amount of energy actually absorbed in some material, and is used for any type of radiation and material. One rad is defined as the absorption of 100 erge per gram of material (rad = 100 erges/g) and Gy =100 rad) (IAEA Vienna 2007). The unit rad can be used for any type of radiation, but it does not describe the biological effects of the different radiations.

2-5-3: Rem (rem):

The rem is a unit used to derive a quantity called equivalent dose. This related to absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effects, even for same amount of absorbed dose. Equivalent dose is often expressed in terms of thousandths of a rem, or mrem. To determine equivalent dose (rem), is multiply absorbed dose (rad) by a quality factor Q that is unique to the type of incident radiation.

2-5-4: Curie (Ci):

The curie is a unit used to measure a radioactivity. One curie is that quantity of a radioactive material will have ($37x10^{9}$) transformations in one second. Often radioactivity is expressed in smaller units tike: (mCi), (uCi), (nCi) of curie. The relationship between curie and Becquerel is (1Ci = $3.7x1o^{10}$Bq).

2-5-5: Gray (Gy):

The gray is a unit used to measure a quantity called absorbed dose. This relates to the amount of energy actually absorbed in some material, and is used for any type of radiation and material. One gray is equal to one joule of energy deposited in one kilogram of a material. The unit gray can be used for type of radiation, but it does not describe the biological effects of the different radiations. Absorbed dose is often expressed in terms of one Gray is equal 100 rads (1Gy = 100 rads).

2-5-6: Sievert (SV):

The sievert is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose. Equivalent dose is often expressed in terms of millionths of sievert (mSV) or micro- sievert (µSV).To determine equivalent dose, is multiply absorbed dose (Gy) by a quality factor Q that is unique to the type of incident radiation. (1SV = 100 rem).

2-5-7: Coulomb Per Kilogram (C/Kg):

The coulomb per kilogram (C/Kg) is the SI unit of ionizing radiation exposure, and it is the amount of radiation required to create one coulomb of change of each polarity in one kilogram matter (CEMBER 1996).

2-5-8: Becquerel (Bq):

The Becquerel is a unit to measure a radioactivity; One Becquerel is that quantity of the radioactive material that will have one transformation in one second. Often radioactivity is expressed in larger units like :(KBq), (MBq), (GBq) of a

Becquerel's. As a result of having one Becquerel is equal to one transformation per second, there 3.7×10^{10}Bq = Ci (CEMBER 1996).

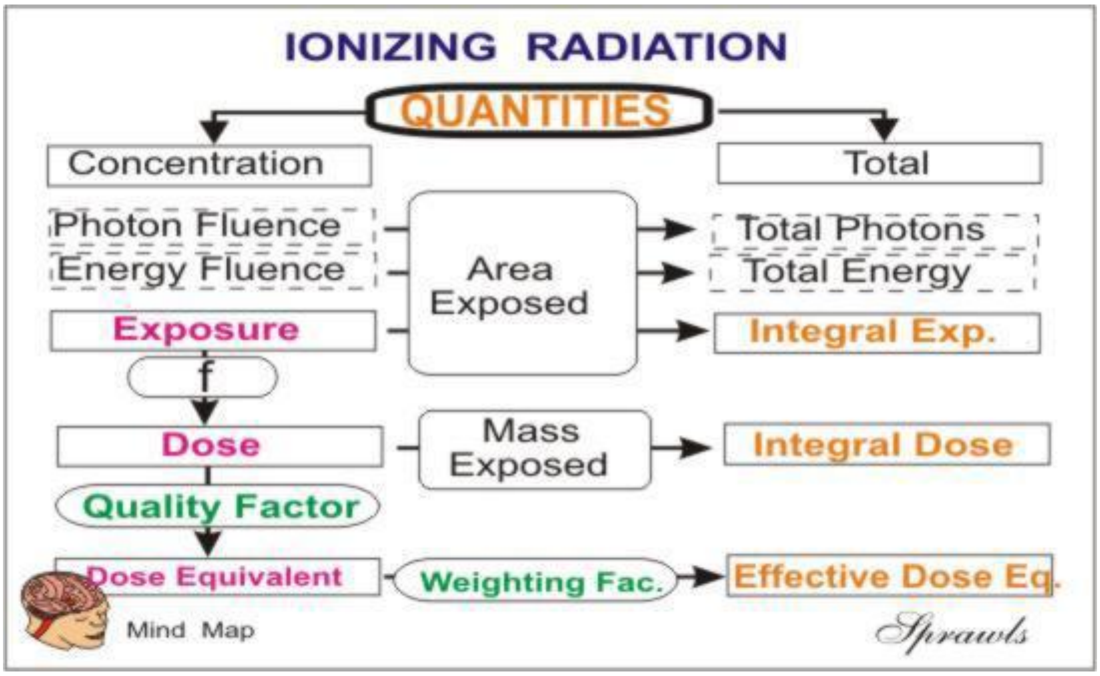


Figure 2- 3: Ionizing radiation quantities and units

Table 2- 4: Radiation unit's conversion factor (Instant conversion for units of radiation on the web since 1996).

Exposure	Conversion unit	SI unit	Conversion
exposure	Roentgen (R)	C/kg	C/Kg =3876R R= 258 u C/kg
Dose	Rad (rad)	gray (Gy)	1 Gy = 100 rad
Dose Equivalent	Rem (rem)	Sievert (SV)	1 SV = 100 rem
Activity	Curie (Ci)	Becquerel (Bq)	1 Ci = 3.7×10^{10} Bq

2-6: Radiation Risk:

Health effects of exposure to x- ray radiation come in two general types, direct or in direct. X-ray is thought to create radical in exposed cells of your body. That may break or modify chemical bonds within critical biological molecules. As result:

i- Skin and cells may be injured or damaged, although May cells repair themselves, resulting in no residual damage.

ii- Cells may be die, which millions of body cells do every day and one replaced in a normal biological process.

iii- Cells may be in correctly repairing themselves resulting in a biological change.

Finally x-ray may pass through the body with no interaction (Khalid Elmahdi 2012).

2-7: Radiation Risk and Biological Effects:

When a radiation falls on the human body it produces moving electrons. Thus electrons ionize exits and lead to chemical and molecular changes. Radiation can also produce free radicals, which are unpaired electron that are chemical reactive, thus radical can also damage tissues, as resulted the constituents of the body cell will be effected. Thus human body will result in biological damage which may appear as clinical systems. An acute delivered in as hart time is more harmful, than a chronic dose delivered over a period of time. The radiation effects which manifest themselves soon after irradiation are called early effects. These effects that manifest themselves after a period of time are called late effect (Thanyain K, 2001).

The harmful effects of radiation classified to:

2-7-1: Deterministic Effects:

A deterministic effects increases in severing with increasing absorbed dose in effected individuals which appear at a high dose (greater than 0.5 Gy) and generally result from cell death and they are characterized by a threshold dose, below which the effect does not occur, deterministic effect include skin erythema, depilation, organ atrophy, fibrosis, cataract induction, blood change and reduction in sperm count (Khalid Elmahdi 2012).

2-7-2: Stochastic Effects:

Stochastic effects in which probability of occurrence increases with increasing absorbed dose rather that its severity. Stochastic means random and the severity of the stochastic effect is independent of the radiation dose. As the radiation increase the change of effect occurring increases and it has not threshold close, may be occur at low dose and effect may be seen only at later period (10- 30 years) these risk are dependent on sex and age at exposure . Stochastic effects classified as:

2-7-2-1: Somatic Effects:

The somatic effects are produced in exposed individuals during their life and it depends on the amount of radiation, the part of the body irradiated, and the age of person. In general the younger person, the more hazardous the radiation.

2-7-2-2: Genetic Effects:

The radiation effect produced successive generation of exposed individual and result of radiation exposure of mutations in the reproductive cells that effect later generation (Khalid Elmahdi 2012).

2-8: Staff Dose Measurement:

Scattered radiation dose were measured at several horizontal and vertical distances from the central axis of the scan table using radical model 9010, 1800cm^2 cylindrical ionization chamber the body scanner water filled phantom was used as a source of scatter radiation. For each distance three exposure measurement ware taken and average calculated scatter radiation measurement at (1m) horizontal distance were also obtained when a person was scanned for the spine left right hip.

TLDs chips were packed in plastic bags in positions numbers. These bags were attached with surgical tape to some members of the body of the main operator as follows doses were measured at the forehead, to measure the dose to the eye lens, at the neck, to measure the dose to the thyroid, at the chest, to measure the dose over lead apron, and at the waist level to estimate the dose to the organs shielded by the apron. Hand dosimeter measured the dose to the upper extremities and leg dosimeters were used to estimate the dose to the lower extremities. While for the assistant, to sits were monitored at the chest and the hand. For the technologist and the circulator, the monitoring site was the chest only; Individual dose monitoring assessed by the measuring ESD was converted in to effective dose using the algorithm proposed (Niklason et al 2003)

2-9 : Measuring Patient And Staff Dose From Absorbtiometric Techniques:

Various practical problems are associated with measuring absorbed dose from body scanners. First the dose rate for a single scan is very low number of repeated scan has to be sued to increase the radiation dose above a detectable limit. There are several computer programs hat compute the effective dose for common radiological procedures but not based measuring dose. The technical problem of applying these programs to patient and staff scanner is that bone densitometers are heaving filtered in order to minimize the beam hardening problem and the half value layer which is required in the problem is difficult to evaluate. The method adopted in this case is conventional method of measuring using TLDS. This method of measurement has been reported in pervious literature (D.Peter2009).

2-10: Radiation Dosimeters:

A radiation dosimeter is a device, instrument or system that measures or evaluates either directly or in directly, the quantities exposure absorbed dose or equivalent dose, or their time derivatives, or related quantities of ionizing radiation. A dosimeter along with its reader is referred to as dosimetry system(Mr. Murarisharma 2004).

Measurement of a dosimetric quantity is the process of finding the value of the quantity experimentally using dosimetry systems. The result of a measurement is the value of a dosimetric quantity expressed as the product of a numerical value and an appropriate unit. To function as a radiation dosimeter, the dosimeter must possess at least on physical property that is a function of measured dosimetric quantity and can be used for radiation dosimetry with proper calibration. In order to useful radiation dosimeters must exhibit several desirable characteristics. For example in radiotherapy exact knowledge of both the absorbed dose to water at a specified point its spatial distribution are of importance as well as the possibility of deriving the dose to an organ of interest in the patient. In this context the desirable dosimeter properties will be characterized by accuracy and precision, linearity, dose rate dependence, energy response, directional dependence and spatial resolution (D. Peter 2009).

2-10-1: Accuracy and Precision:

In radiation dosimetry the uncertainty associated with the measurement is often expressed in terms of accuracy and precision. The precision of dosimetry measurement specifies the reproducibility of the measurement under similar conditions and can be estimated from data obtained in repeated measurements. High precision is associated with small standard deviation of the distribution of the measurement results. The accuracy of dosimetry measurements is the proximity of their expectation value to the true value of measured quantity.

Results of measurements cannot be absolutely accurate and the in accuracy of a measurement result is characterized as uncertainty.

The uncertainty is a parameter that describes the dispersion of the measured values of a quantity; it is evaluated by statistical methods or by other methods has no known sign and is usually assumed to be symmetrical. The error of measurement is difference between the measured value of a quantity and the true of that quantity.

- An error has both a numerical value and sign.

- Typically the measurement errors are not known exactly, but they are estimated is the best possible way.

- After application of all known corrections, the expectation value for errors should be zero and only quantities of concern are the uncertainties (D.Peter 2009).

2-11: Dose Instrumentation:

Throughout the department of energy's history, various types of instrumentation have been used to detect and quantify radiation levels and radiation doses to individuals. These include classic radiation detection instruments such as handheld dose rate meters, contamination monitors, continuous air monitors, as well as dosimetry used to measure the dose received by individual. Currently there ongoing initiatives to reevaluate past radiation exposure received by individuals. These are based on historical records of surveys from radiation detection instruments and personnel dosimetry records. These radiation dose reevaluations employ current dosimetry models to best estimate life time radiation exposures. These handouts provide an overview of historical and current radiation monitoring and personnel dosimetry capabilities used by the department of energy's. The handout describes the purpose and process of radiation dose assessment and should help the reader understand the capabilities and limitations of measuring radiation dose by some dosimeters (Midshipman et all 2003).

2-11-1: Thermoluminescence dosimetry (TLDs):

Thermoluminescence dosimetry is based on the physical phenomenon that various materials emit part of absorbed ionizing radiation energy as visible light upon heating the exposed material. The phenomenon is found in many insulators and semiconductors of natural and synthetic origin. The process of light emission upon heating is called thermoluminescence (TL). Application of thermoluminescence are found in solid state physics archaeology, environmental studies clinical dosimetry for medical therapeutic purposes research in health physics and least but not least is dosimetry for occupational exposed persons (Maria B,2003).

Small TL- element designed for radiation dosimetry is called TLDs. In the literature the term TLDs may refer to the bare element as well as to a group of elements encapsulated in a holder. Generally dosimeters for personal dosimetry consist of the plastic holder in which removed sets of TL-element are placed. Most of the time additional filters are placed in the holder in front of TL-elements. As these filters result in differences in the attenuation of incident radiation and thereby in different TL-signals of the TL- elements placed behind these filter, dosimeters can provide insight in the radiation quality (Stephen 2002).

TLDs have several limitations as a method for determining patient dose from fluoroscopy. Information is not provided during the procedures. The variable locations of the X-ray beam make it difficult to place TLDs so that they will appropriately record the doses of in interest. This is especially difficult if the maximum dose to the skin is the quantity of interest. We will use the term peak skin dose (PSD) to refer to the highest dose delivered to any individual portion of the skin during a procedures. A point measurement with a TLD chip requires advance knowledge as to the location of PSD on the patient. This information is seldom available. Techniques for using arrays of TLDs characterize fluoroscopic dose distributions. The increase numbers of chips complicates logistics. Even when arrays are used unless the separation between the TLDs is quite small it is quite likely that the TLDs would not be placed so as to record the PSD. AT least one dosimetry service provides arrays of TLDs intended for monitoring the dose distributions resulting from fluoroscopy. Such a service might be of interest to a facility wishing to assess initially or periodically the dose distributions typically resulting in their facility without investing in the equipment to do so it house (Marjlyn et al 2004).

The TLDs were readout using a Harshaw reader. This provided at three phase heating cycle. The first is a low temperature per readout anneals to empty any low temperature traps prone to fading. The second is measurement phase were the light output is integrated as the temperature is raised. The final phase is short, high temperature post readout anneal that enable a check to be made that readout was complete (Mr. Murarisharma 2004).

2-11-2: Ionization Chamber:

Ionization chamber consists of a volume of gas between to electrodes help a potential difference of around 300V. As radiation enters the volume the gas is ionized and ion pairs are produced. Each ion pair will be drawn to wads the opposite electrode. A signal is detected which is proportional to the amount of radiation absorbed. Air filled ionization chambers were used to calibrate the depth dose by accurately measuring the entrance surface dose (ESD). They were also used to check the TLDs measurement of the depth dose. The ionization chambers used entrance dose was Radical model 9010 calibrated on 3o November 2001.

The use of an ionization chamber connected by a cable to an electrometer has the advantage of separating the contributions from difference part of the examination, such as dose to scout scan and total dose to whole scan. Also the results are displayed instantly unlike the TLDs. However its finite thickness affects its spatial resolution making disadvantageous to use high dose gradient areas

(Qydis, Q et al 2008).

2- 11-3: X-ray Film Dosimetry:

Patient for diagnostic and interventional x-ray procedures, using various types of film has been described by number of investigators. Dosimetry using film has the advantages of providing a detailed indication of the location of the skin dose, providing quantitative dose information with careful calibration and densitometry and being used any x-ray system.

Certain films have a working range from o.o1Gy to about 2Gy. This is sufficient for many procedures but too sensitive for very complex interventional procedures. Even is this cases the film can demonstrate the distribution of dose and quantitatively indicate those skin locations where the dose exceeded the upper limit of the useful range of the film sensitivity. These films reveal complex and quite different dose distributions as recorded on the film (Stephen 2002).

2-11-4: Radiographic Film

Radiographic x-ray film performs several important functions in diagnostic radiology, radiotherapy and radiation protection. It can serve as a radiation detector, a relative dosimeter, a display device and an archival medium. Unexposed x-ray film consists of base of thin plastic with a radiation sensitive emulsion coated uniformly on one or both sides of the base.

Ionization of AgBr grains as a result of radiation interaction forms a latent image in the film. This image only becomes visible and permanent subsequently to processing. Light transmission is a function of the film opacity and be measured in terms of optical density (OD) with device called densitometers.

The OD is defined as OD = log (I_0/I) and is a function of dose. I_0 is the initial light intensity and it is the transmitted through the film. Film gives excellent 2- D spatial resolution and, in a single exposure, provides information about the spatial distribution of radiation in the area of interest or attenuation of radiation by intervening objects. The useful dose of film is limited and the energy dependence is pronounced for lower energy photons. The response of the film depends on several parameters, which are difficult to control. Consistent processing of the film is a particular challenge in this regard. Typically film is used for qualitative dosimetry, but with proper calibration, careful use and analysis film can also be used for dose evaluation. Unexposed film would exhibit a background OD called the fog density.

The density due to radiation exposure, called the net OD, can be obtained from the measured density by subtracting the fog density. OD readers include film densitometers laser densitometers and automatic film canners. The relationship between the dose and OD should be linear, but this is not always the case. Some emulsion is linear, some are linear over a limited dose range and others are non-linear. The dose versus OD curve, called the sensitometric curve (characteristic curve OD, exposure) must therefore be established for each film before using it for dosimetry work. Typical applications of a radiographic film in radiotherapy are qualitative and quantitative measurements, including electron beam dosimetry, quality control of radiotherapy machines verification of treatment techniques in various phantoms and portal imaging(IAEA 2004).

2-12: Preview of Study:

Interventional cardiology which involves diagnostic and therapeutic procedures is becoming progressively more common. Staff and patient dose during cardiologic procedures is considered to be high due the existence of the operators beside the patient while x-ray procedures undergoing and the prolonged exposure time to the patient. Since no enough assessments were made at the national level to estimated the significance of radiation dose to the patient and staff thus radiation dose measurement required (hiba et al 2010).

The number of cardiology interventional procedures has significantly increased recently. This is due to the reliability of the diagnostic equipment to diagnose many heart diseases. In the procedures the x- ray used results in increasing radiation doses to the staff. The cardiologist and the other staff members in interventional cardiology are usually working close to the area under examination and receive the dose primarily from scattered radiation from the patient. Therefore workers in interventional cardiology are expected to receive high doses. The annual doses received by workers do not exceed 20mSv.

The volume of diagnostic or therapeutic procedures in cardiology that require the use of ionizing radiation is increasing constantly. Currently technological development offers the possibility of exploring not only the cardiac function but the state of coronary and great vessels. In fact the management of patient with heart disease often requires the use of investigative techniques using X-rays (Verdum et al 2011).

The increase in radiological examinations using ionizing radiation has been mentioned for several years in professional medical journals and the press addressing the general public.

While most examinations deliver relatively low dose and thus add only a low risk to the procedure itself there are situations where doses exceed the dose level where an excess risk of death from cancer has been demonstrated. In addition some complex procedures may result in the occurrence of deterministic effects such as burns to the skin. The substantial increase of fluoroscopy guided procedures in cardiology over the past few years has been accompanied by a parallel growth in concern for patient radiation safety and for the safety of the operators who perform these procedures. Thus radiation safety bas become a major issue in radiology departments (Andreas et al 2009).

There are many reports in the literature of cases where patients suffered radiation skin lesions even necrosis after interventional cardiology procedures during which the radiation dose delivered during fluoroscopy and cinematography exceeded the threshold of deterministic skin effect (dose threshold 2-6 Gy for erythema,3Gy for hair loss, 18 Gy for necrosis). The dose value and any consequent radiation related complications are related to many factors. Fat patients receive a higher dose, since the automatic exposure control system increases the functional parameters of the tube and hence radiation output in order to achieve satisfactory imaging. The complexity of the individual lesion and the ability of the invasive cardiologist to perform fine manipulation of the catheter in the region of interest also affect the total exposure time, which is directly proportion al to patient radiation dose. The imaging technique (patient focus distance , image intensifier field size, X-ray field size, low fluoro- pulse rate, short cine recording time, low cine frame rate,etc.) .

The physical quantity with the greatest interest in the radiation protection of patients undergoing invasive cardiological procedures is the entrance skin dose, since the patient's skin, more any than other tissue will be exposed to the radiation. The physical quantity dose area product (DAP) determines patient dose, and provides information about the irradiated skin surface area. The skin dose can be extracted from DAP if the irradiated skin surface area is known, conversely the dimensions of the field can be determined if the skin dose is known. The skin dose may also be determined indirectly from a meter placed in the exit of the X-ray tube, provided the X-ray focus to skin distance is known. However during an examination the focus to skin distance changes, as do the size of X-ray field and the image intensifier magnification making it difficult to measure or even estimated the dose. Another way of measuring the patient's dose is by placing thermoluminescent dosimeters (TLDs) or film or both in the region where the X-ray beam enters the patient body. The simultaneous use of TLDs and film allows accurate measurement with information about the distribution of the dose on the skin but it is a time consuming and costly technique. Thus the measurement of DAP was the method of choice for patient dosimetry in the present study since it allows a fast and reliable estimation of the patients skin dose.

Based on studies that investigated the relationship between DAP and entrance dose measured with film and TLDs and on proposed factors for conversion of

DAP to effective dose, we also evaluated the effective dose received by patient in the hemodynamic laboratory and hence the stochastic risk of the procedure (Dr. Peter 2009).

The radiation dose measured for staff during cardiac catheterization was using TLDs. They found the statistical of ESD values to eyes, thyroid, chest, waist, hand and legs of the main operator, the cardiologists. The dose to the leg is drastically higher in relation to the other organs due to its proximity to the scanning plane when using under couch x- ray tube. Therapeutic procedures result in high dose to staff per procedure since this procedure require a longer fluoroscopy time, They concluded that the staff dose measurement is of prime importance and practitioners should optimize the radiation. The annual effective dose received by cardiologists during cardiac catheterization procedures are relatively high 0.04mSv per procedure the nurses, x-ray technicians and circulator are exposed to 0.01mSv per procedure (Hiba H., Abdelmoneim 2010).

The patient dose in cardiac radiology by ionization chamber, the median values of DAP were (19.96- 40.17) Gy.cm^2, fluoroscopy time were (7.7- 23.4) minutes and the numbers of frames were (457- 641) for coronary angiograph and angioplasty respectively. There was a strong correlation between DAP and fluoroscopy time, the number of frames per sequence, and hence the cine recording time, they concluded that the entrance skin dose delivered to the patient in the hemodynamic department was lower than that of other studies. Although the mean fluoroscopy time per patient was longer, the practices in use satisfy the diagnostic reference levels as far as DAP values and number of frames per patient are concerned, but not with regard to fluoroscopy time,(Verdum Francis 2011).

Personal dosimetry in interventional cardiology in the period 1999-2004 the total dose measurements 420, were performed 176 dose measurements outside the lead apron on left sleeve, 34 outside the lead apron at the collar and 210 inside the lead apron. The measured doses median on the left sleeve varied (1.5-6.0) mSv/4weeks and at the collar between (o.5- 2.8)mSv/ 4 weeks. These results differed significantly between the three interventional cardiologists. The measured doses on the left sleeve were significantly higher than the measured dose at the collar. The difference in measured dose on the left sleeve compared to at the collar for group of interventional cardiologists was factor 1.9.

The results of the measurement inside the lead apron varied between (o.o2- 0.12) mSv/ 4 weeks. The measurements inside the lead aprons differed significantly between the three interventional cardiologists (Gerritjan Kuipers, 2009).

The TLDs Harshaw 6600 Reader was used in the assessment of effective dose for Hp (10). Two TLDs were used by each workers at three cardiology centers one worn under a protective apron and the other worn outside and above the apron as specified by the ICRP. Each worker at the other sections was facilitated with one dosimeter to be worn on the chest. The annual doses received by 14 cardiologists, 13 nurses, and 9 technologists at the three cardiology centers were in range :(0.84- 4.77), (0.15- 2.08), (0.32- 1.10)mSv respectively, INMO (NMDRI).

In the INMO the annual doses received by 7 doctors, 5 nurses and 14 technologists were in range: (0.13- 0.51), (0.11- 0.65) and (0.03- 1.39)mSv respectively. The results showed that the annual doses received by the workers do not exceed 20mSv

Estimated effective dose to staff from interventional procedure, using two personal dosimeters for all physicians were involved in interventional procedure, the mean and median of the doses measured outside and under lead aprons of the physicians are shown. Additionally the 25th and 75th percentiles as well as the minimum and maximum dose measured outside the lead aprons ranged from 0.53- 4.24mSv /4 weeks while the mean doses under the lead aprons ranged from 0.01- 0.18mSv in weeks. The highest dose measured outside the lead apron was 16.78mSv in 4 weeks, while under the lead apron a maximum dose up to 1.17mSv was measured in 4 weeks the lowest dose measured on both sides of the lead apron was < 0.01mSv. This was the case for 2.8% of measurements outside the lead aprons while under lead apron 22% of the measurements were < 0.01mSv. The dose measured under the lead apron (Gerritjan Kuipers 2011).

Study was performed to measure radiation dose to staff involved in fluoroscopically guided interventional cardiology (IC) procedure. 33 staffs were monitored 39 IC procedures performed during 4 week period in two most occupied cardiology centers in Khartoum, Sudan. Staffs were 15cadiologist, 13 nurses and 5 radiographers. Radiation doses were measured using electronic personal dosimeters (EPD) type RAD-60 with Energy compensated si-Diode detectors (RADOS, Finland). Prior to experimental measurements, EPDs were calibrated in three X-ray qualities described in the ISO 4037 narrow spectrum series a viable at the secondary standard dosimetry laboratory. EPDs were calibrated to measure personal dose equivalent, using ICRU slab phantom.

For occupational dose assessments, each staff was provided one EPD worn on chest above the lead apron and read immediately after the procedure. Effective doses were estimated from the measured personal dose equivalent Hp (10) using single dosimetry algorithm. Based on the calibration resulted, the selected EPDs performed satisfactorily in X-ray qualities indicated. Cardiologist received the highest doses, followed by nurses and then technologists,

Estimated median and maximum effective doses per year presented. The maximum effective doses up to 1.4mSv per year were estimated. The calculated effective doses were well below the annual dose limits of 20mSv per year, recommended, (ICRP 2007).

TLDs were carried out to evaluate radiation doses from diagnostic chest x- ray examinations in three pediatric hospitals in Khartoum area. Entrance skin doses (ESDs) were determined from x- ray exposure parameters for pediatric patients undergoing chest anterior- posterior (AP) and posterior- anterior (PA) examinations using pre- established relationship between tube output and tube voltage (KVp) encountered in practice. Mean ESDs obtained in chest AP projection ranged from 130- 194µGy for patients with age 0-1 year, 154- 249µGy for patients with age 1-5 years. Mean ESDs obtained for chest PA projection ranged from 110-199µGy for patients with age 1-5 years and from 118-134µGy for patients with age 5- 10 years. An effective (ED) obtained range from 8.1-37µGy. The results revealed the extent of doses incurred by patients examined in these hospitals with slight improvement from a previous work. However they exceeded the international established reference doses. There is a need for adherence to international recommendations and codes of good practice as a means for further dose reduction, by(Ibrahim I. Suleiman 2007).

The study was performed to reduction of radiation doses to patient and staff during endoscopic retrograde cholangiopancreatography for fifty seven (57) patients was studied using digital x- ray machine and thermo luminescent dosimeters (TLDs) to measure ESD at different body sites. Organ and surface dose to specific radiosensitive organs carried out. The mean, median, minimum, third quartile and the maximum values are presented due to the asymmetry in data distribution. There found the mean ESD, exit and thyroid surface dose were estimated to be 75.6mGy, 3.22mGy and 0.80mGy, respectively. The mean effective dose for both gastroenterologist and assistant is o.o1mGy.The mean effective dose was 4.16mGy, and the cancer risk per procedure was estimated to be 2×15^{-5}. It concluded with fluoroscopic technique, demonstrate improved dose reduction, compared to the conventional radiographic based technique, reducing the surface dose by factor 2, without compromising the diagnostic findings. The radiation absorbed doses to the different organs and effective doses are relatively low (Abdelmoneim et al 2011).

CHAPTER THRREE

Material and Methods

This chapter describes the use of TLD chips to potentially measures the entrance surface doses, dose area product (DAP, describes interventional procedures techniques and C- arm machines.

3-1: Dosimeters:

In the present study, staff dose measurements during interventional cardiology procedures were made using TLDs chips manufactured by France FIMEL Company. TLDs made of Lithium Fluoride doped with Magnesium copper, and phosphorus (LiF:Mg,Cu,P)), circular type, with physical size 4.5mm in diameter and 0.8mm in thickness, linear response from 1μGy to12Gy,showing in the **fig3-1**

Fig. 3-1: TLDs envelope

(LiF:Mg,Cu,P) is starting to replace (LiF,Mg,Ti) in Varity of personnel dosimetry applications. LiF,Mg,Cu,p has superior characteristics as compared to LiF, Mg, Ti including higher sensitivity, improved energy response lack of supralinearity and insignificant fading. The LiF, Mg,Cu,p is large scale dosimetry programs is of particular interest due to the extreme sensitivity of this material to the maximum readout temperature, and the variety of different dosimetry aspects and details that must be considered for a successful implementation in routine dosimetry. A program to upgrade the systems and implement LiF, Mg,Cu,p started in the 1990 and was recently concluded in the 2002, the new system replacing the CaF_2:Mn system in 2006. A pilot study to determine the dosimetric performance of the new. LiF,Mg,Cu,p based dosimetry system was recently completed and the result show the new system to be as good as or better than the current system in all areas tested. As a result, LiF,Mg,Cu,p is scheduled to became the primary personnel dosimeter(H.Osman 2012).

3-2: TLDs Calibration

The accuracy of measurement of the TLDs used was calculated using a known dose from a calibrated test dose. The total error was estimated to be not more than ± 1%.

General purpose C-ram machine was used for calibration of TLDs. The Simulator is manufactured by Huestiscascade NTM- radiation therapy, Germany Company in 2010, type Simulator fixed, max voltage 150KV to radiography- 125KVp to fluoroscopy ,max mA 0.5- 1000mAs, focal spot 0.6- 1.0mm,total filtration is 2.5mm at 80Kv and installation in the 2012.

The calibration was performed manually. A number of 50 TLD chips were calibrated using detector .

Each three chips were loaded together in one polyethylene plastic envelope.

These assemblies were irradiated using a beam quality of 70KVp, 60mA, 10mAs using simulator machine, and this exposure factor selected because this energy was dominant in interventional procedure.

The TLDs positioned at 100 cm for machine (tube focal spot) positioned to the central ray. This procedure has been repeated for 16envelops. By using the same setting as illustrated a set of measurements were taken using PTW- CONNY ionization chamber in **Fig (3-2)** with dimensions of 180x100x45 mm, applicable to cardiology and surgery. The measured doses were 5.119mGy at all constant.

The irradiated chips were readout using automatic TLDs reader FIMEL PCL3 (France) resulted in 50 signals. The average signal (TL_m) was calculated using the Microsoft Excel function or Spss function then the calibration factor (ECF) for each TLDs chip was determined using the following equation

$$\frac{TLs}{TLm} = \mathbf{ECF} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{3\text{-}1}$$

$$ECF = TL_s / TL_m \ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{3\text{-}2}$$

Where: TL_s TLDs signal in nano Colum for individual TLDs

TL_m the mean value of the signals.

The process was repeated three times to reduce the effect of statistical variation and to determine the stability reproducibility of signal.

$$\text{Total ECF each TLDs} = \frac{ECF1+ECF2+ECF3}{3} \ldots\ldots \mathbf{3\text{-}3}$$

the unknown absorbed dose is given by the equation

$$D = ECF \times M_i \text{-------------} \mathbf{3\text{-}4}$$

Where: M_i net signal of TLDs

ECF element calibration factor

After ended the calibration process, any element exceeds 10% error was excluded (2chips) and remaining chips were used to carry out the study measurements (48 chips), this ratio was selected because the diagnostic was 25% to avoid error and be more precise it was selected to be 10%(ICRP 2007).

Fig 3-2: CONNY II dosimeter

3-3: TLDs reader

The TLD reader with control software (FIMEL PCL3 reader) and an annealing oven (furnace RS232 interface with THELDO software) along with other accessories, including a vacuum tweezers, an oxidized aluminum annealing planchet with 100 depressions and a reading planchet.

A thermoluminescent dosimetric system consists of several parts as follows:

- The passive elements: the TL dosimeters (or detectors).

-A TL reader schematically consisting of a heating element, a PM tube, one or more electronic networks.

-An appropriate algorithm to convert the TL signals (response of the reader) to dose. -Ovens and/or furnaces to be used for thermal treatments of the dosimeters (annealing procedures). any other complementary instrumentation or facility which can be used for the right setting up and working for the system and/or for the implementation of the system (i.e. calibration sources; programme able to make an automatic estimation of the background, to calculate the average TL values and so on).

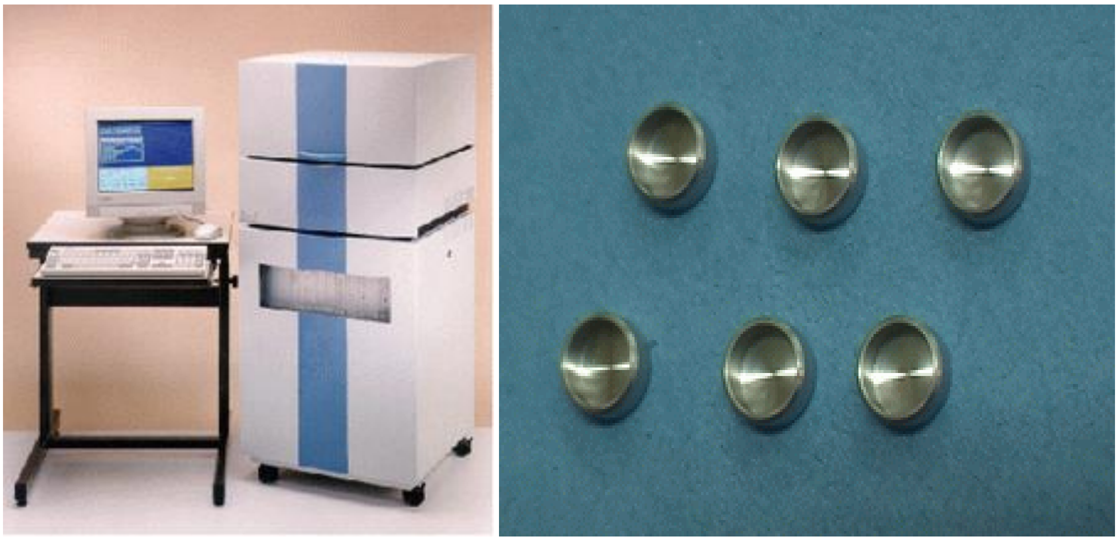
The TLD chips handling must be gently and carefully to prevent dusty and scratching .For this reason we used the vacuum tweezers **Fig (3-3)**.

Is basically attached to a tiny vacuum pump via a flexible silicon tube. You control the vacuum by placing your finger over the hole on the shaft of thin stainless steel shaft with a tiny suction cup on the end.

Fig 3-3: vacuum tweezers.

3.4: Readout cycle

Since the fading of TLD-100H disks is negligible, the time interval between the irradiation and the readout is not crucial. Nevertheless, irradiated TLD disks were read out at least 16 hours after irradiation for all the measurements.



A B

Fig 3-4: A, PCL3 reader &B, couples

PCL3 is an automatic reader Figure (3-4, A), developed for reading thermoluminescent products in a powder form or solid form. The dosimeters are placed in metal containers Figure (3-4, B) couples stored in a loading magazine Figure (3.5). They are then moved from one position to the next (preheating, reading) then moved to an unloading magazine. The dosimeters are automatically read without any intervention. In all the readouts, this time varied from 3 to 10 minutes.

Fig 3-5: loading magazine

3.5: Annealing cycle

Annealing is the thermal treatment needs to erase any irradiation memory from the dosimetric material. Before using a thermoluminescent material for dosimetric purposes, it has to be prepared. To prepare a TL material means to erase from it all the information due to any previous irradiation, i.e, to restore in it the initial conditions of the crystal as they were before irradiation. The preparation also has the purpose of stabilizing the trap structure.

In order to prepare a thermoluminescent material for use, it is needed to perform annealing ("ICRP Publication 60,1990), carried out in oven or/and furnace, which consists of heating up the TL samples to a predetermined temperature, keeping them at that temperature for a predetermined period of time and then cooling down the samples to room temperature.

Microprocessor- controlled oven for precise and reproducible heating of TL detectors. Suitable especially for TL chips, rods and films (ribbons). Includes two standard temperature programs for preheating and annealing arbitrary temperature levels based on both standard profiles are programmable by optional software.

The TLDs annealing oven Figure (3.6) is designed for very precise and reproducible temperature treatment of TLD material. During the heating cycle, the hot air stream is circulated by a built-in fan to ensure equal temperature distribution throughout the oven volume. Even the cooling.

Figure 3-6: Preheating and annealing oven with two standard programs;

Programmable via an RS232 interface with THELDO software

Phase is temperature controlled. A digital display shows the actual temperature, and built-in lamps indicate the program progress.

After that, when all TLD disks were readout, they were put on an oxidized aluminum annealing planchet, which then was put into the annealing oven for 10 minutes annealing in 240°C. This temperature could be manually set on the front panel of the oven. TLD-100H would be damaged in a higher temperature; therefore one had to make sure the 240°C limit was not exceeded.

3-6: Staff ESD Measurement:

Staff dosimetry measurements were performed for 61 examinations, main operators and assistants. The data of staff to three sites of the body of the main operator as follows: doses were measured at the hand to measure the doses to the upper extremities, at the chest to measure the doses over lead apron, and at the waist level to estimate the dose to the organs shield by apron. While for the assistant at the chest for the technologist the monitoring site was the chest only, are given in **appendix**-1. In all procedures staffs entrance surface dose were a valuated using three envelope include three TLDs chips in a plastic envelop mounted on staff surface at midpoint of radiation field at a part of interest of the central axis beam using a very thin envelope made of transparent polyethylene plastic tail, to protect the TLDs form any contamination an avoid any shadow in the monitor. During interventional cardiology procedures the TLDs were kept in required position and fixed in place with cell- tapes to measure ESD.

3-7: Patients (DAP) Measurements:

Patient dosimetry measurements were performed for **212** adult patients. The data used in this study was collected from Alshaab teaching hospital, Ahmed Gasim teaching hospital Khartoum state - Sudan. The main objective of this study was evaluating and assessment the patient dose during the interventional cardiological procedures. The following parameter was recorded such as (age, weight, height, clinical indication, sex and type of procedures) are given in **appendix-2.** In all procedures patient dose area product were evaluated using DAP in included to the C- arm machine.

The patient dose categorized according to the types of procedures and the mean ESD was calculated for each examination. Additionally the effect doses were estimated for measured ESD using appropriate conversion factor found in the literature.

3-8: C-arm X-ray Machines:

Two different c-arm machines were used throughout this study. As describes in the table below- table (3-1). Two of them equipped with high frequency (HF) generator and have last image hold capability. Air Kerma Product (AKP) was not available for all machines, all machines have ability to pulse fluoroscopy but operator used both continues and pulse beam during different procedures. The machine describes are shown in table 3-1 below.

Table 3-1: C- arm machines Specifications

Generator Type	Type	Focal spot	filtration	Max KV	Max mA	Installation date	Manufacturing date	Model
HF	Fixed	0.6-1.0mm	1.5mm	150	1000	2007	2007	Shimadzu

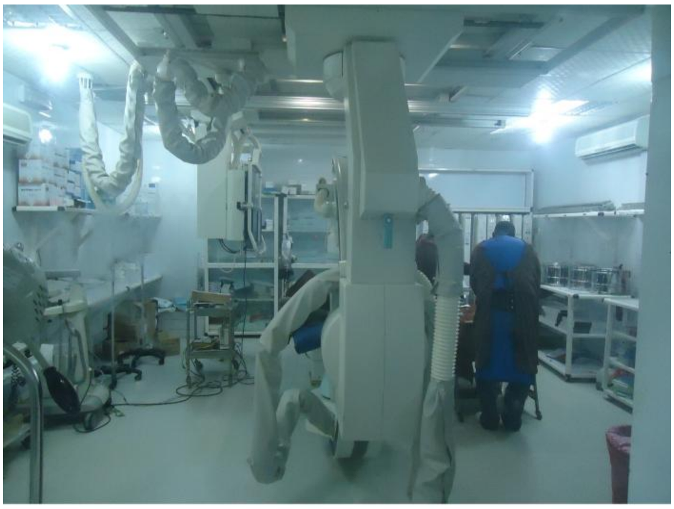


Fig 3-7: Machine(cath-lab in Alshaab hospital)

3- 9: Absorbed Dose Calculation:

Entrance surface dose can be defined of the absorbed dose to air at the centre of the beam including backscattered radiation, the exposure to skin of the patient standard radiographic examination or fluoroscopy can be measured directly or estimated by a calculation to exposure factors used and equipment specification for equation below:

ESD = OPx $\left(\frac{KV}{80}\right)^2 \text{x} \boldsymbol{mAs}\left(\frac{100}{FSD}\right)^2 \mathbf{BSF}$ ………**3-5**

Were:

OP is the output in(mGy/mAs) of the X-ray tube at 80 at a focus distance of (1m) normalized to (10 mAs), KV the tube optional, mAs the product of the tube current (in mA) and exposure time (in seconds), FSD the focus to skin distance (in cm), BSF the backscatter factor, the normalization at 80KV and 10 mAs was used as the optional across the X- ray tube and the tube current are highly stabilized at this point.

BSF is calculated automatically by the Dose Cal Software after all input data are entered manually in the software. The tube output the patient or staff anthropometrical data and radiographics parameters (KV, mAs, FSD and filtration) are initially inserted in the software. The kind of examination and project are selected after mad's.

3-10: Dose Calculation:

The radiation dose was determined by two ways one directly by TLD with TLDs reader and other is theoretical by (output factor, kVp, mAs, SSD and back scatter factor).The first one estimate the ESD according to the following equation:

D(mGy) = $\frac{\boldsymbol{TL-BGR/ECF}}{\boldsymbol{TLms/Ds}}$ …….. **3-6**

Where:

D(mGy) : dose in mGy

Tl: TLDs signal

BGR: background signal

ECF: element correction factor

TL_{ms} : mean signal from TLDs irradiated to standard dose

Ds: standard dose

In this study DAP meter was used for measuring patients dose. DIAMENTOR M4 (PTW, Germany Company) is a state of the dose area product (DAP) as shown in Fig: (3-8). The dual channel device measures the total procedures during radiography and fluoroscopy according to international regulations. Its digital display can simultaneously show the reading from both channels. In addition exposure time during fluoroscopy is measured without the need any connection to an X-ray generator. The RS232 interface enables data transfer to a computer. Features of dual channel device for single plane and bi- plane fluoroscopic and radiographic X- ray unites:

- Complies with international standard IEC 60580.
- Displays the selectable DAP units (Gycm^2, mGycm^2 and Rcm^2).
- Measures fluoroscopy exposure time from beam analysis.
- Displays DAP rate during fluoroscopy, switches automatically over to DAP after examination.

Fig 3-8: DAP meter

3-11: Estimation of organ dose and cancer risk

The organ equivalent doses and effective doses were calculated using NRPB.262 software. ESD was used as an input parameter for the estimation of the organ equivalent dose. The risk of developing cancer in a particular organ following fluoroscopy guided interventional or genetic effects in future generations after irradiation was estimated by multiplying the mean organ equivalent dose with the risk coefficients obtained from ICRP-60(1991).

$CP = D_m x R_f$:……….. **3-7**

Were:

CP: cancer probability.

D_m: mean organ equivalent dose.

R_f : risk factor.

It is well know that radiation induced cancers cannot be distinguished from those produced by other possible carcinogenic agents because of the high natural incidence and the long latent period. Therefore cancer risk estimation depends on the observation of a number of cancers of different kinds that arise in irradiated groups

3.12: The effective dose estimation for staff

Individual dose monitoring assessed by measuring entrance surface dose has been converted into effective dose. When apron protective shields are used, and two dosimeters, one worn over lead apron at the chest level and under the apron at the waist level, the effective dose (E) would be given by formula:

$E = 0.06(Hos - Hu) + Hu$ ……….. . **3.8**

Where, Hos: measured dose at the chest level.

Hu: measured dose under the waist level.

CHAPTAR FOUR

THE RESULTS

4-1 Results:

Cardiac catheterization has been used frequently for the evaluation and treatment of patient's heart diseases. It has become an essential technique to practice of cardiology. The part of these techniques is fluoroscopy. Although there have been many fluoroscopic technical advances that significantly reduced radiation dose, such as the use of pulse fluoroscopy, high doses are still possible in long and complex procedures. The likelihood of high doses demands that attention be given to possible deterministic and stochastic effects in some cases of the vascular interventional procedures. Pediatric patients are even more susceptible than adults to effective ionizing radiation, further increasing the importance of quantifying and minimizing patient doses (Marta et al 2011). During interventional procedures, patient is partially exposed to the radiation. In addition various dose descriptors were frequently used in patient dose measurements. Therefore, patient dose must be reported in the form of the effective dose because it allows comparison of dose burden between different imaging techniques and procedures. The effective calculated on the basis of the relative radiosensitivity of the various organ exposed, which are assigned a weighting value by International Commission on Radiological Protection (ICRP 2007).For each organ dose indentified by the (ICRP).The absorbed dose to organ is scaled by tissue weighting factor, and this product is summed for all organs to calculate the effective dose .Because it is practically impossible to directly measure organ dose during clinical procedures, effective dose must be determined indirectly. In general indirect estimates of effective dose can be achieved the through technical methods, through conversion factor applied to direct skin surface dose measurements, or through direct dose measurements with dosimeters inserted into phantoms that are exposed at radiologic settings mimicking the clinical procedure

(Bardredin 2012). There were several studies have been performed is this field, but more of them will help to protect the patient and staff from relatively high potential hazard.

The main objective of this study was evaluation for patient and staff radiation doses and risk estimate. And to provide staff dose measurement during cardiac catheterization using TLDs chips dosimetry and with DAP meter to measure patient dose. It is known that the radiation exposure received by an individual staff (main operator and assistant) usually related to the workload of the patients, the type of procedures being performed, the technique employed, the age of patient, distance from X-ray tube focal spot to patient, standard performance of the image intensifier, X- ray system used and type of C-arm machine is used in the procedure. Staff exposure dose was much greater when large C- arm was used compared to mini C- arm, higher exposure rates are encountered compared to values reported by(Brian et al, 2009). Therefore since this study has used large C-arm machines in all catheterization examinations. From the results obtained researcher extracted that the highest radiation dose to PCI procedure than CA procedure from the patient and staff.

The data used in this study was collected from Alshaab teaching hospital and Ahmed Gasim teaching hospital Khartoum state - Sudan. The main objective of this study was evaluating the patient and staff doses during interventional cardiological procedures. The following parameter was recorded such as patient body characteristic **BMI** (age, weight, height, clinical indication, sex and type of procedures)**.** In all procedures patient dose area product were evaluated using (DAP) meter in included to the C- arm machine. Total procedures in this study are 212 procedures, 161(87male and74 female) in diagnostic catheterization (CA) procedures and 51(24 male and 27 female) in therapeutic catheterization (PCI) procedures, are given in the **table4-1**. The statistical summary of patient body characteristic in the study is given in the **table 4-3**. Body mass index (BMI) considerable variations were observed among patient population in terms of radiation dose, and fluoroscopic time.**Table4-4** and **table4-5** are given the statistical summary of patient body characteristics in CA and PCI procedures respectively. Radiation dose(DAP) values to patient's higher in relation to the body characteristic due to the scanning plane when using under couch X- ray tube in procedure, are shown in **table 4-6**. The therapeutic procedure result in high dose to patient and longer fluoroscopy time than diagnostic catheterization are given in **table 4-7** and**4-8**respectively.

A total of staff dosimetry measurements were performed for 61 examinations (43for CA and 18for PCI procedure) in two hospitals is given in the **table 4-9.** The study was included the two kind of the staff, main operators and assistants. The data of staff to three sites of the body of the main operator as follows: doses were measured at the hand to measure the doses to the upper extremities, at the chest to measure the doses over lead apron, and at the waist level to estimate the dose to the organs shield by apron. While for the assistant at the chest for the technologist the monitoring site was the chest only. In all procedures staff entrance surface dose (ESD) were a valuated using envelope include three TLDs chips in a plastic envelop mounted on staff surface at midpoint of radiation field at a part of interest of the central axis beam using a very thin envelope made of transparent polyethylene plastic tail, to protect the TLDs form any contamination an avoid any shadow in the monitor. During interventional cardiology procedures the TLDs were kept in required position and fixed in place with cell- tapes to measure ESD.

The statistical summary of the entrance surface dose (ESD) value received to staff, the hand, chest and waist of main operator and chest to assistant operator in cardiac catheterization to the CA and PCI procedures are shown in the table**4-10, 4-11**andTable**4-12**respectively.

Table 4- 1: No of patients in the study

Clinical Indication	Male	Female	Total
CA	87	74	161
PCI	24	27	51
Total	111	101	212

Table 4- 2: No of clinical indication in tow hospitals

Clinical Indication	Hospital		Total
	Alshaab	A-Gasim	Total
CA	134	27	161
PCI	33	18	51
Total	167	45	212

Table 4-3: Statistical summary of patient body characteristic

	Age(year)	Weight(kg)	Height(cm)	BMI(kg/cm2)
N	212	212	212	212
Mean	57.42	76.02	167.25	27.319
Median	57.00	77.50	167.00	26.416
Std. Deviation	11.651	12.108	10.801	4.7224
Minimum	21	44	120	15.3
Maximum	85	108	190	43.3

Table 4-4: Statistical of patient body characteristic in CA procedure

	Age(year)	Weight(kg)	Height(cm)	BMI(kg/cm2)
N	161	161	161	161
Mean	57.40	76.30	167.41	27.423
Median	57.00	78.00	167.00	26.534
Std. Deviation	11.571	11.128	10.688	4.7257
Minimum	21	47	120	15.3
Maximum	85	108	190	43.3

Table 4-5: Statistical of body Characteristic in PCI procedure

	Age(year)	Weight(kg)	Height(cm)	BMI(kg/cm2)
N	51	51	51	51
Mean	57.45	75.14	166.75	26.989
Median	59.00	77.00	167.00	26.260
Std. Deviation	12.019	14.878	11.244	4.7434
Minimum	32	44	145	20.0
Maximum	82	103	189	38.7

Table 4-6: Statistical summary of exposure parameter

	Kv	mAs	SSD (cm)	mG/cm2	time(m)	NO of films
N	212	212	212	212	212	212
Mean	86.17	5.592	110.72	917.07	6.870	9.17
Median	86.37	5.504	111.15	732.65	4.480	8.00
Std. Deviation	8.320	.8436	2.854	68.174	7.0593	4.532
Minimum	63	3.2	92	118	.5	3
Maximum	105	10.2	115	4430	47.3	33

Table 4-7:Statistical summary of dose value in CA procedure

	Kv	mAs	SSD (cm)	mG/cm2	time(m)	NO of films
N	161	161	161	161	161	161
Mean	85.94	5.581	110.49	642.69	4.4320	7.54
Median	86.11	5.460	110.83	583.00	3.4400	7.00
Std. Deviation	8.003	.8207	2.735	30.02	3.4960	1.924
Range	41	7.1	22	1541	25.05	11
Minimum	63	3.2	92	118	.48	3
Maximum	105	10.2	115	1659	25.53	14

Table 4-8:Statistical summary of dose value in PCI procedure

	Kv	mAs	SSD (cm)	mG/cm2	time(m)	NO of films
N	51	51	51	51	51	51
Mean	86.91	5.628	111.45	1783.25	14.567	14.31
Median	86.62	5.632	112.00	1493.60	12.180	13.00
Std. Deviation	9.297	.9197	3.118	81.5647	9.5714	6.269
Minimum	64	3.2	100	418	2.5	5
Maximum	105	8.7	115	4430	47.3	33

Table 4-9: No of Staff in clinical hospital

Clinical Indication	Hospital		Total
	Alshaab	A-Gasim	Total
CA	32	11	43
PCI	12	6	18
Total	44	17	61

Table 4- 10: Statistical summary of staff radiation dose values (mGy)

	P-dose	hand dos	chest dose	waist dose	Ass- dose	fluo-time
N	61	61	61	61	61	61
Mean	905.48	.2125	.1127	.0608	.0134	6.7592
Median	759.90	.1784	.0982	.0573	.0113	4.4900
Std. Deviation	6.698	.1193	.0516	.0356	.0072	2.4771
Minimum	159.2	.0483	.0221	.0123	.0064	.46
Maximum	3654.3	.6009	.2717	.1579	.0405	31.11

Table 4-11: Statistical summary of staff radiation dose values (mGy) in CA

	P-dose	hand dos	chest dose	waist dose	Ass-t dose	fluo-time
N	43	43	43	43	43	43
Mean	585.68	.1848	.1045	.0544	.0123	3.716
Median	574.00	.1572	.0951	.0502	.0106	3.260
Std. Deviation	235.81	.0941	.0485	.0345	.0063	2.2996
Minimum	159	.0604	.0221	.0123	.0064	.5
Maximum	996	.4072	.2717	.1323	.0405	10.6

Table4- 12: Statistical summary of staff radiation dose values (mGy)in PCI

	P-dose	hand dos	chest dose	waist dose	Ass-t dose	fluo-time
N	18	18	18	18	18	18
Mean	1.6690	.2786	.1321	.0763	.0161	14.029
Median	1.3410	.2548	.1354	.0812	.0135	13.025
Std. Deviation	7.5470	.1476	.0547	.0340	.0085	7.4572
Minimum	1030.3	.0483	.0379	.0158	.0064	2.5
Maximum	3654.3	.6009	.2524	.1579	.0356	31.1

CHAPTER FIVE

DISCUSSION, CONCLUSION and RECOMMENDATIONS

5-1: Discussion

5-1-1: Patient dose:

The use of radiation in medicine may be one of the difficult areas for ensuring a balance between risk and benefit. Medical professionals are responsible for evaluating the risk and benefit to determine if x-ray procedure is warranted. Some of contributing factors in the observed variation of patient's exposure can be attributed to the use of suboptimal imaging equipment, poor choice of technical factors due to the tack of experience. The result of this dose survey provides valuable data for awareness of situation of patient's doses in Alshaab and Ahmed Gasim teaching hospital in Khartoum state- Sudan. It is the first step to evaluation and reduction of patient dose program. Although many patients derive great diagnostic (CA) and therapeutic (PCI) benefit from interventional cardiology procedures, the use of ionizing x- ray constitutes an associated hazard which must be justified by the procedures benefits. In general variations in **BMI** and exposure factors influence the patient dose, films contrast image and time of fluoroscopic was considered to this study. In this study patients radiation dose was measured for (212) patients, were classified according to their clinical indications, in the two groups ,161 in coronary angiography (CA) procedures and 51 in percutaneous coronary interventions (**PCI**) procedures undergoing interventional cardiac catheterizations procedure are shown in the **table4-1**. The patient's age was ranging from 21to 85 year old from two groups, means of body mass index (BMI) was 27.32± 4.72 kg/cm^2 was range (from 15.3 to 43.3), were comparable as illustrated in the **tables 4-3**, **4-4, 4-5**respectively. The mean exposure factors were 86.17±8.32KVp, 5.92±o.8436mAs, 6.86±7.059mins, 111.15±2.854 (SSD/cm), 9.17±4.532 films per procedure in the CA and PCI procedures was compared in the **tables 4- 6, 4-7** and **4-8** respectively. While the mean values of the (DAP) meter was found to be 917.07 ± 68.17mGy/cm^{2}for both diagnostic and therapeutic (642.69 ± 30.02mGy/cm^2 for diagnostic procedures and 1783.25 ± 149.36for therapeutic procedures) to all patients, this values are lower than similar procedures in literature preview are reported by (Badreldin et al 2012) in the **table 5- 1**. It is well known that occupational doses of radiation in interventional procedures guided to fluoroscopic time, type of **IC** procedure and the number of imaging films, the radiation dose rate are decreases as distance from x- ray tube focal spot (SSD) increases. Therefore the duration time of catheterization examinations and number of films to be a guidance of patient dose.

Table 5-1: Comparison of dose values (DAP) meter with literature

Reference	CA (Gy/cm^2)	PCI (Gy/cm^2)	Year
Micha et al	109 55.9	163 91.8	1997
Micha et al	60.1 27.3	NA NA	2000
Micha et al	29.2 47.3	75 68	2003
A.Trianni et al	39.8±19.1	71.6±39.0	2006
ANDRETSIS ET AL	33±18.8 2.7± 2.4	83.2±62.6 10.0 ± 6.8	2009
Current study	0.643 ± 0.003	1.783 ± 0.816	2014

Their correlation found between BMI and fluoroscopy exposure factors for two groups are shown in figures blow:

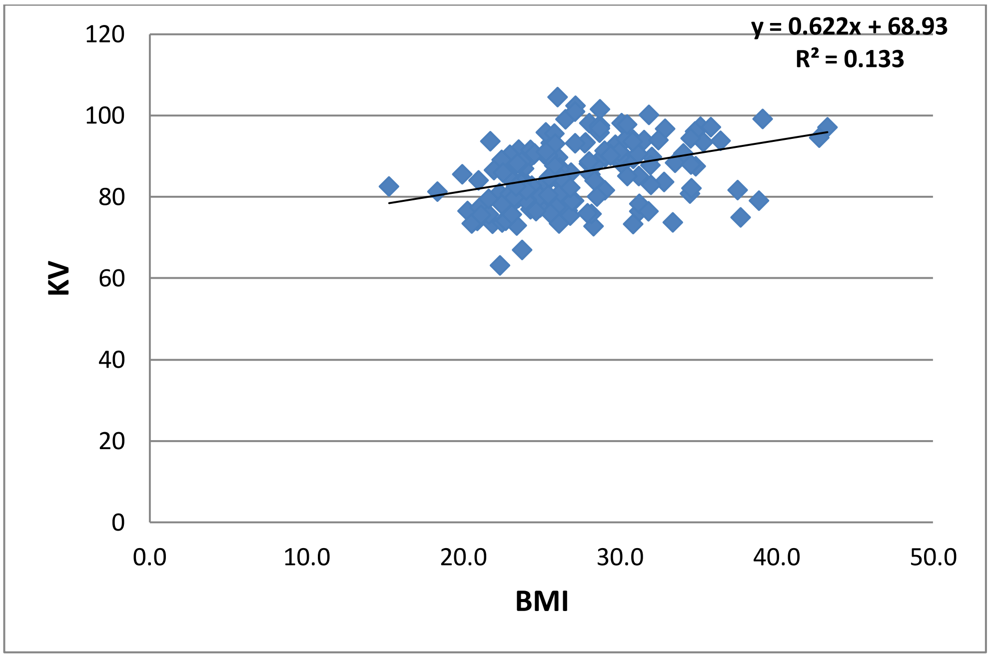


Fig- 5-1: Correlation between BMI and KVp in the CA procedures

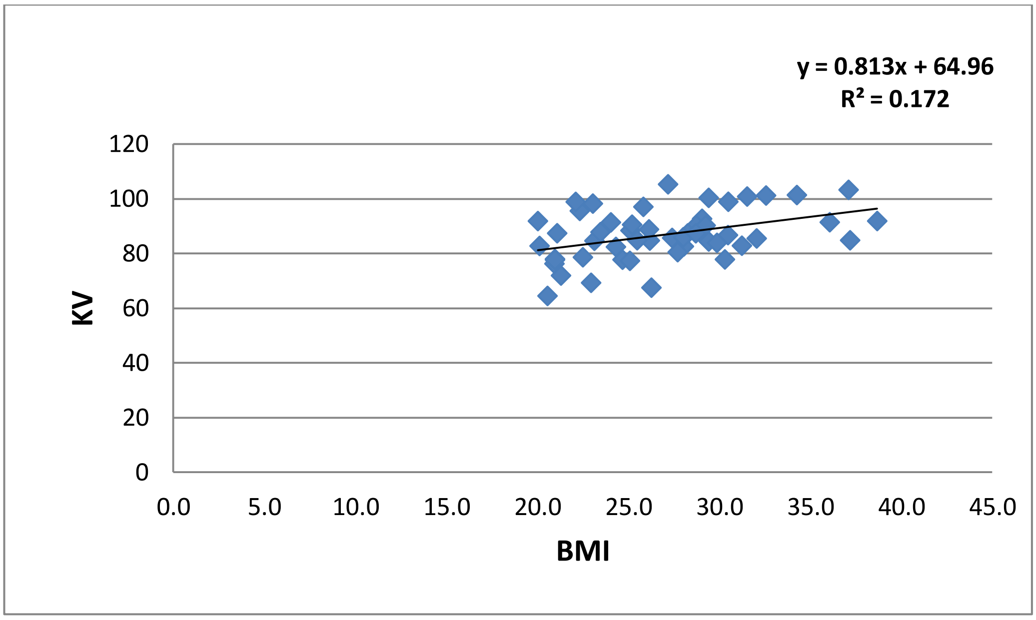


Fig-5-2: Correlation between BMI and KVp in the PCI procedures

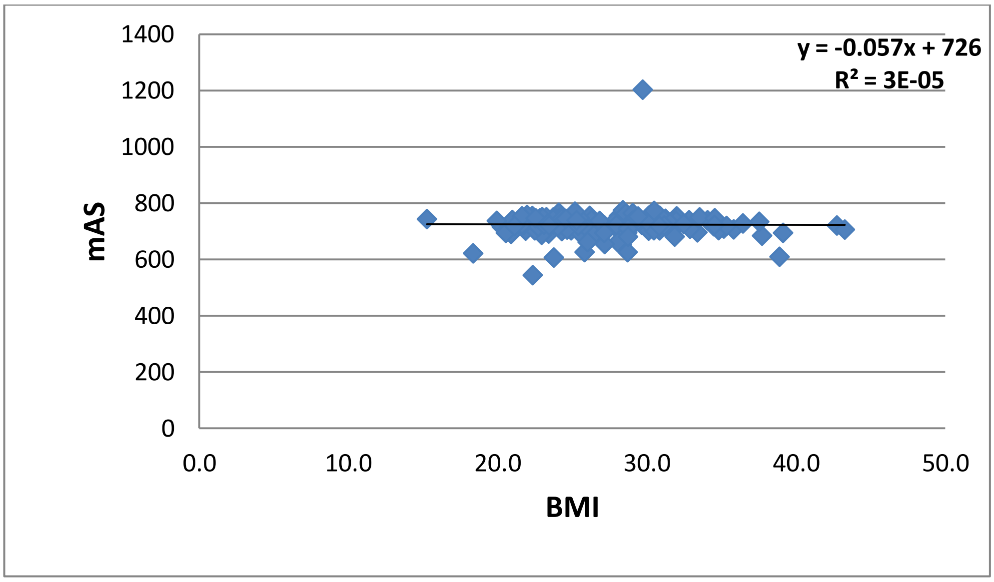


Fig- 5-3: Correlation between BMI and mAs in the CA procedures

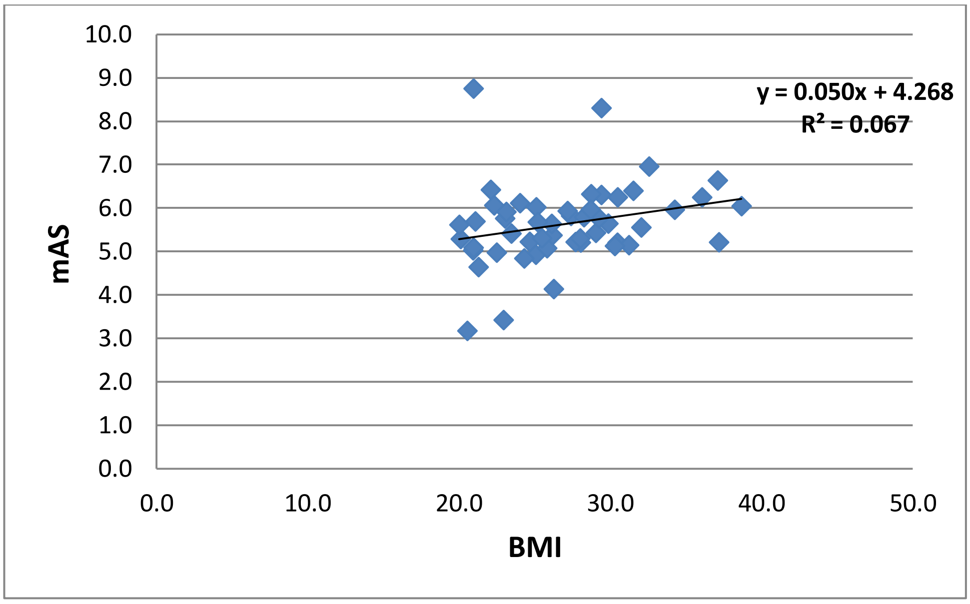


Fig-5-4: Correlation between BMI and mAs in the PCI procedures

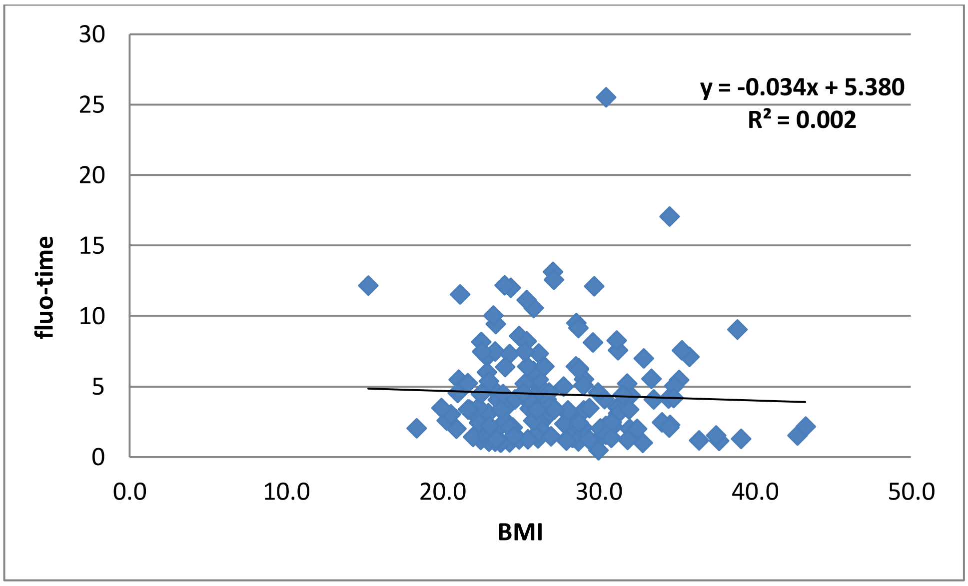


Fig- 5-5: Correlation between BMI and Fluo- time in the CA procedures

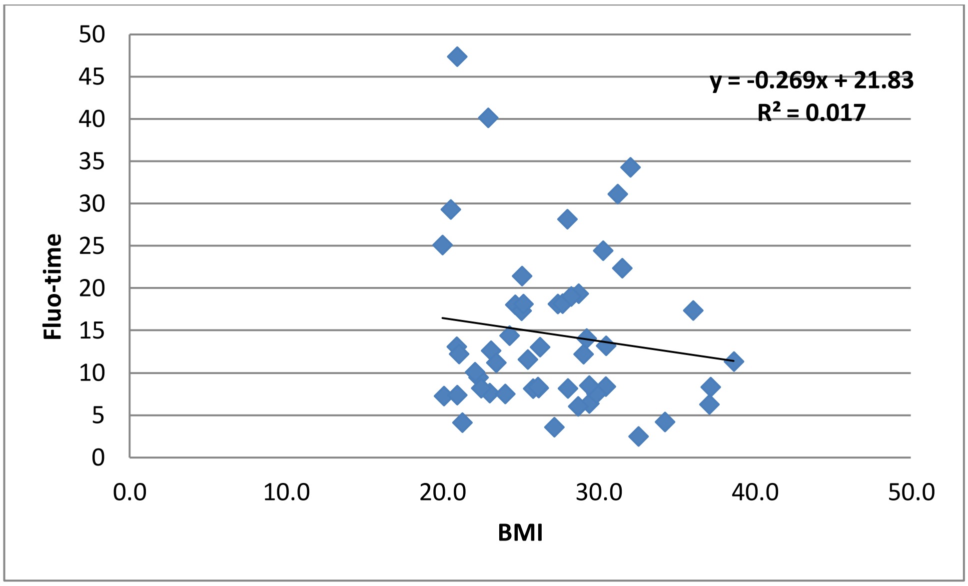


Fig- 5-6: correlation between BMI and fluo-time in PCI procedures

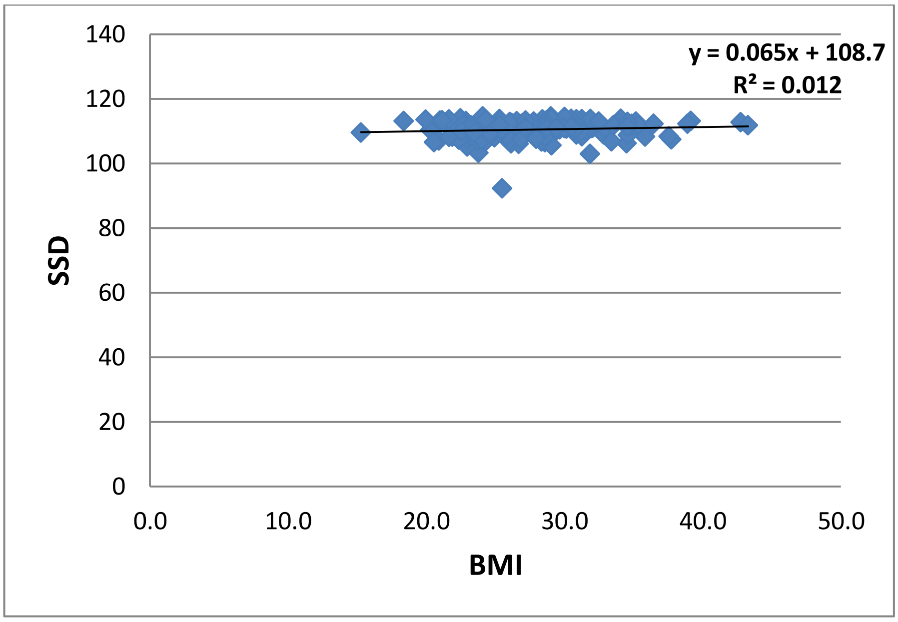


Fig- 5-7: Correlation between BMI and SSD in the CA procedures

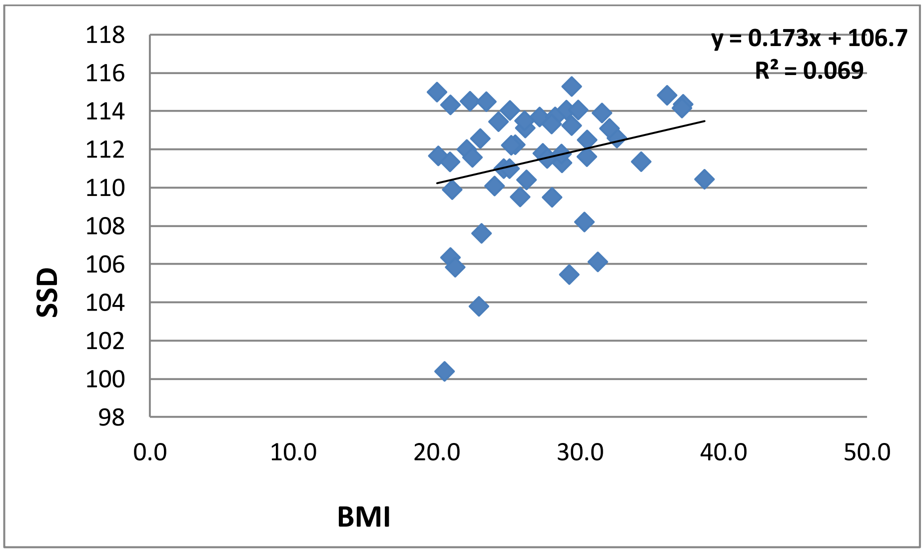


Fig- 5-8: Correlation between BMI and SSD in the PCI procedures

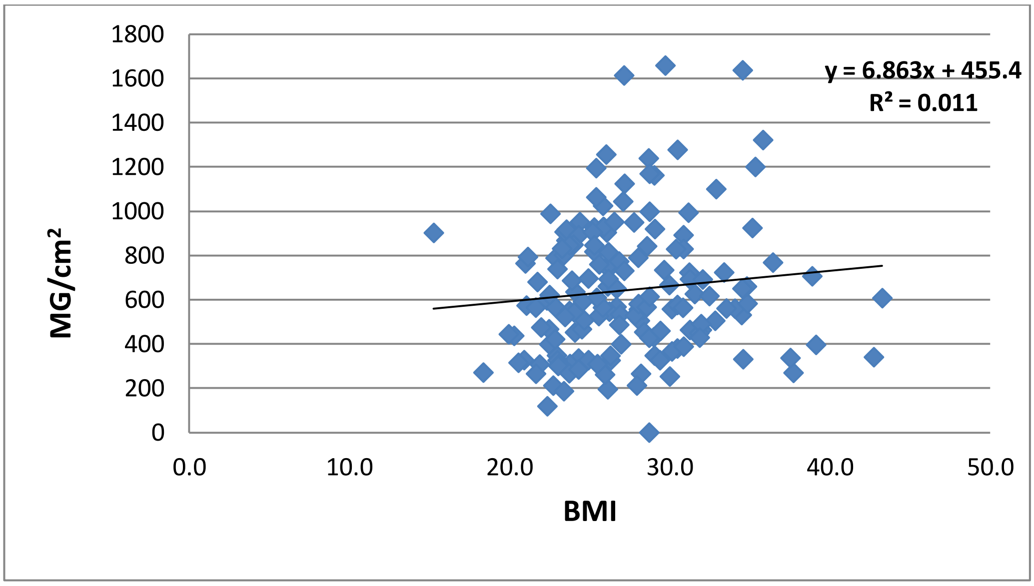


Fig- 5- 9: correlation between BMI and mGy/cm^2 in the CA procedures

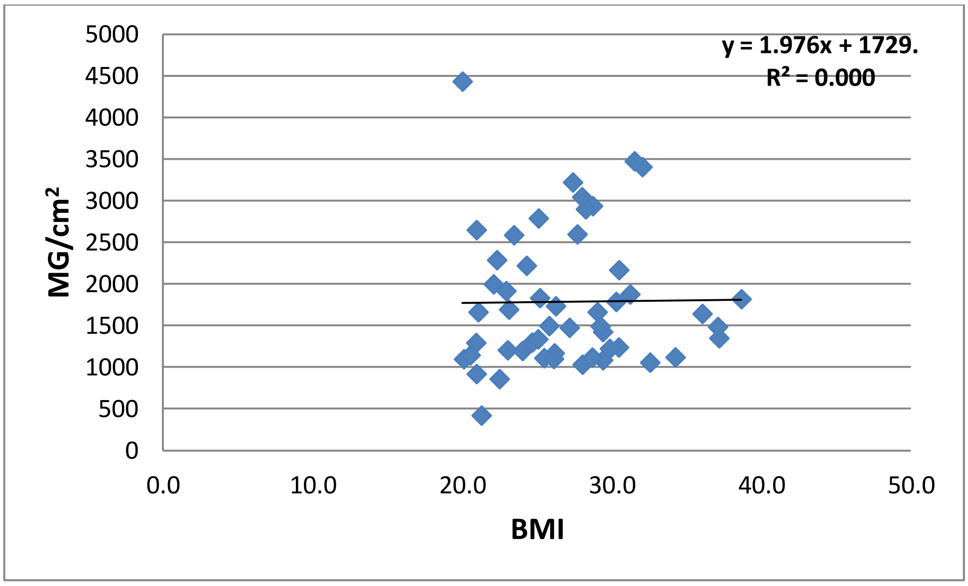


Fig- 5-10: Correlation between BMI and mGy/cm^2 in the PCI procedures

They are a correlation was found between fluoroscopy time and patient radiation dose (R^2 = 0.458 for CA and R^2 = 0.355 for PCI), between number of films and dose received to patient (R^2 = 0.290 for CA and R^2 = 0.260 for PCI) are shown in figures below.

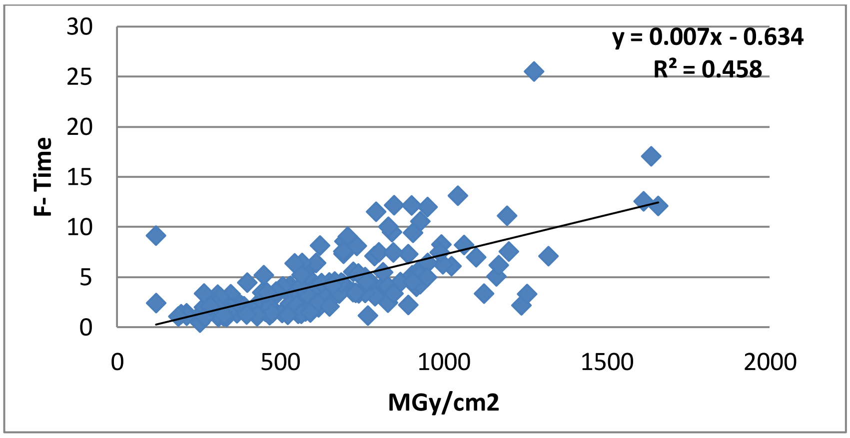


Figure 5-11: correlation between mGy/cm^2 and Fl-time in the IC procedures

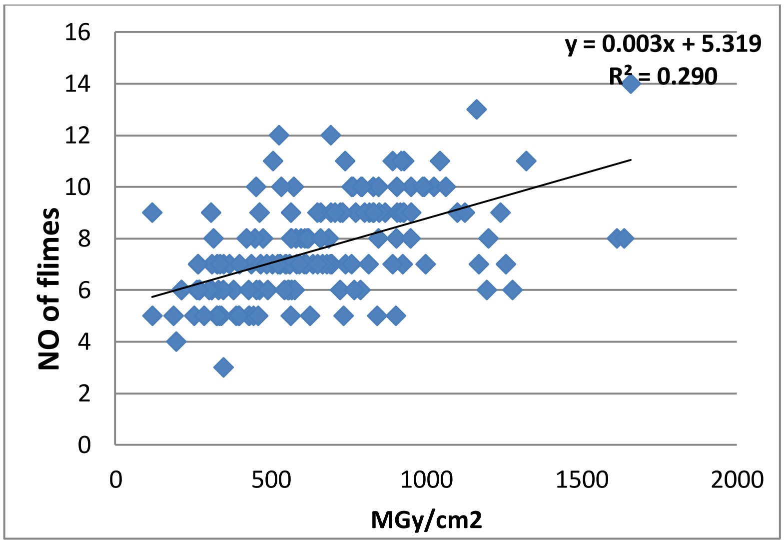


Figure 5-12: correlation between mGy/cm^{2}andNOof films in the IC procedures

5-1-2 Staff dose:

Staff dosimetry measurements total of (61) procedures were performed in the clinical hospital aforementioned in order to measure staff radiation dose for interventional cardiac catheterization procedure. The procedures was divided in two group according to the types of clinical indication performed, group A diagnostic (CA) at (43) procedures and group B therapeutic (PCI) at (18) procedures are given in the **table 4-9** to main operators and assistants doses. These two types of procedures were selected for this study because they are must clinical hospital performed and often require significant number of examinations.

The data of the staff radiation dose was selected to three sites of the body to the main operator as follows: doses were measured at the hand to measure the doses to the upper extremities, at the chest to measure the doses over lead apron, and at the waist level to estimate the dose to the organs shield by apron. While to the assistant at the chest for the technologist the monitoring site was the chest only. In all procedures staff entrance surface dose (ESD) were a valuated using three envelope include three TLDs chips in a plastic envelop mounted on staff surface at midpoint of radiation field at a part of interest of the central axis beam using a very thin envelope made of transparent polyethylene plastic tail, to protect the TLDs form any contamination an avoid any shadow in the monitor. During interventional cardiology procedures the TLDs were kept in required position and fixed in place with cell- tapes to measure ESD.

Dose monitoring to staff and patient during cardiav catheterization procedures and re-evaluation of equipment and used techniques examination is necessary, are mandatory to keep and reduction radiation risk as low as reasonable achievable.
The main source of scatter radiation received to staff is the patient. Several factors can modify the radiation risk to the staff, but if patient doses are high, the level of scatter doses also will be high. **Table 4-10** shown the statistical summary of the staff radiation dose, an increase staff doses depended with patient dose, time of procedures and type of clinical indication, the different value doses received to staff in CA and PCI procedure are comparing in the **table 4-11**and **4-12** respectively. The staff doses measurement and evaluation in this study illustrate that, the highest dose values were obtained from the main operator, lower extremity in the waist (0.0608±0.0356)mGy for all procedures, was ranging (from 0.0123 to 0.1579)mGy. The reason for this result is that the waist is the closest organ to x-ray tube under table and no lower body protection to absorb radiation dose underneath the patient table and to shield the lower extremities of examiner are provided, the mean dose value for chest on the dosimeter over the apron was o.1127±0.0516mGy, was ranging (from0.0221 to 0.2717)mGy, the mean value of

hand without apron was 0.2125±0.1193mGy was ranging (from 0.0483 to 0.6009)mGy for all procedures, it is was higher than waist and chest because the hand is located at a proximity to the field of scattered radiation. The waist and chest dosimeters were used to evaluate the significance of the use of lead aprons as a protection tool, and also to estimate the effective dose. When the mean value dose received by assistant at chest on dosimetry over the apron was 0.0134±0.0072mGy was ranging (from 0.0064 to 0.0405)mGy, it is lower than main operator because the main operator acts as a barrier between the assistant and the scatter radiation according to their positions during the procedure.

In this study the radiation dose to the staff were measured per procedure during interventional catheterization procedures ,they found that therapeutic (PCI) procedure require more fluoroscopic time, hence higher fluoroscopic exposure factors and long duration time per procedure compared to the (CA) procedure, results in more scattered radiation and consequently more radiation dose received to the staff. According the (IC) procedure indicator, should take care about shielding and distance to minimize radiation exposure during interventional examinations.

The mean equivalent dose to the waist was 0.14mSv, which agrees with that reported in previous studies (Hiba et al 2010), were as for the chest is was 0.16mSv, hand 0.18mSv.

The effective dose to the main operator in this study was found to be 0.002mSv per procedure. Each main operator performs about four operators per day, four times a month on once a week basis, considering the annual leave, the national holidays, any malfunctioning of equipment, and lack of supplies, consequently, the main operator may perform about 768 operators a year, resulting in an annual effective dose was1.536mSv to the hand, 0.802mSv to chest and 0.418mSv to waist for CA procedure, were in the hand was 2.304mSv, 1.0138mSv to the chest and 0.768mSv to the waist for PCI procedure. This value is approximately equal to annual limit for effective dose of occupationally exposed personnel, which is20mSv (Recommended **by ICRP- 60**). Because of the high work load, the estimated value is considered high compared to the previous study. The value dose estimated in this study it is under acceptable from the radiation protection of view study. It a great extend, catheter labs are often operated by physician with no formal training on the physics of fluoroscopy and on radiation protection issues. The cardiologist and the rest of medical staff should be made aware of associated radiation risk and the radiation protection equipments. The staff doses in this study it is lower than similar procedures in literature preview study are compared in the table **5-2**.Therefore the patient dose, fluoroscopy time and clinical indication to be a good indicator of scattering radiation to receive by medical staff. Controlling one of these parameters is expected to reduce drastically doses to staff.

The risk of developing cancer in a particular organ following cardiac catheterization procedure after irradiation was estimated by multiplying the mean organ equivalent dose with risk coefficient factor obtained from the recent (ICRP 2007), while the lifetime mortality risk per procedure resulting from tissue reactions was determined by multiplying the effective dose by the risk factor. In this study the mean effective dose for main operator was estimated to 0.002mSv per procedure which is equal $2x10^{\mathbf{-6}}Sv^{-1}$ and the fatal cancer and hereditary effects per procedure was found to be $2x10^{\mathbf{-8}}Sv^{\mathbf{-1}}$(nominal risk coefficients $10^{\mathbf{-2}}Sv^{\mathbf{-1}}$ for stochastic effects reported by Evolution of ICRP recommendations 1977, 1990 and 2007)

To obtain a reasonable assessment of craniological risk for the staff, account should be taken the irradiation of all the radiosensitive organs of the body. As the dose limit recommended for the hand 500mSv per year. With the average dose of 0.002mSv it would require 250000 procedures to reach that dose. From these results with correct workload, the staff dose lower acceptable limits, bearing in mind that wearing the protect shield to reduce the radiation doses to the staff.

Table 5-2: Comparison of staff doses values (mGy) with literature

Reference	organ	mean	min	max	Year
Hiba et al	Waist Chest Hand assistant	o.14 0.19 0.18 0.14	0.08 0.12 0.10 0.07	0.24 0.73 0.48 0.18	2010
H.Osman et al	Waist Chest Hand assistant	NA 0.20 0.23 NA	N A 0.16 0.21 NA	NA 0.28 0.26 NA	2012
Current study	Waist Chest Hand assistant	0.0608 0.1126 0.2125 0.0134	0.0123 0.0221 0.0483 0.0064	0.1579 0.2717 0.6009 0.0405	2014

A correlation was found between patient dose and main operator doses as follows: (R^2 = 0.130), (R^2 = 0.124, (R^2 = 0.128), hand, chest and waist respectively. The correlation between patient dose and assistant dose measuring in chest are given in the relation (R^2= 0.143).These parameters are shows in the figure: 5-13, 5-14, 5-15 and 5-16repectvely.

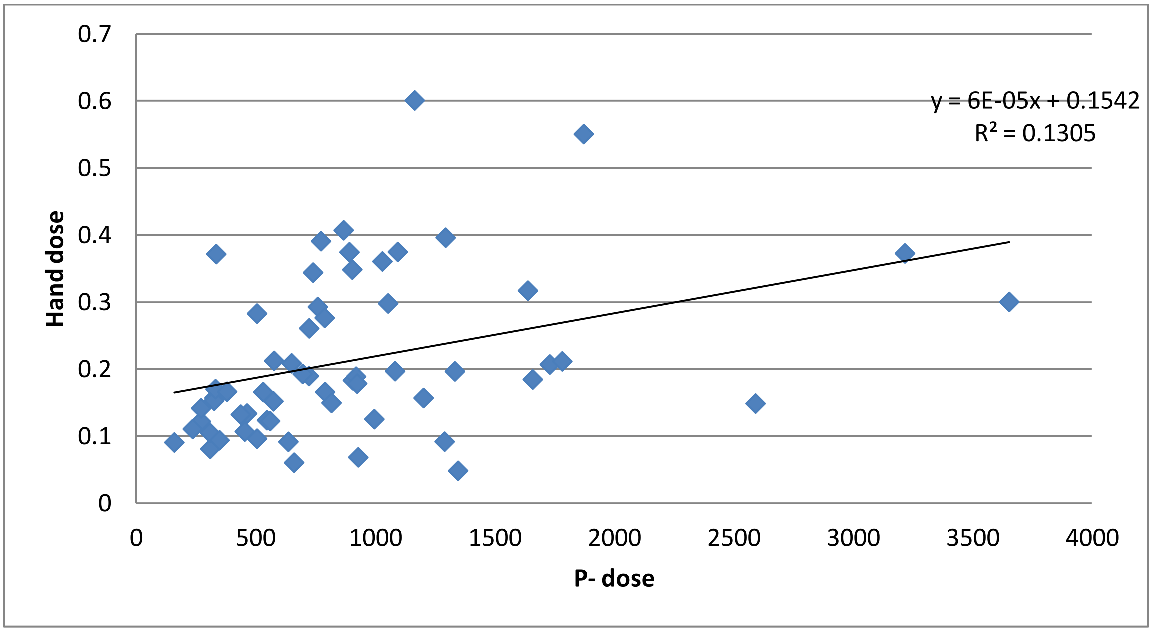


Figure: 5-13 correlation between patient dose and operator dose in hand

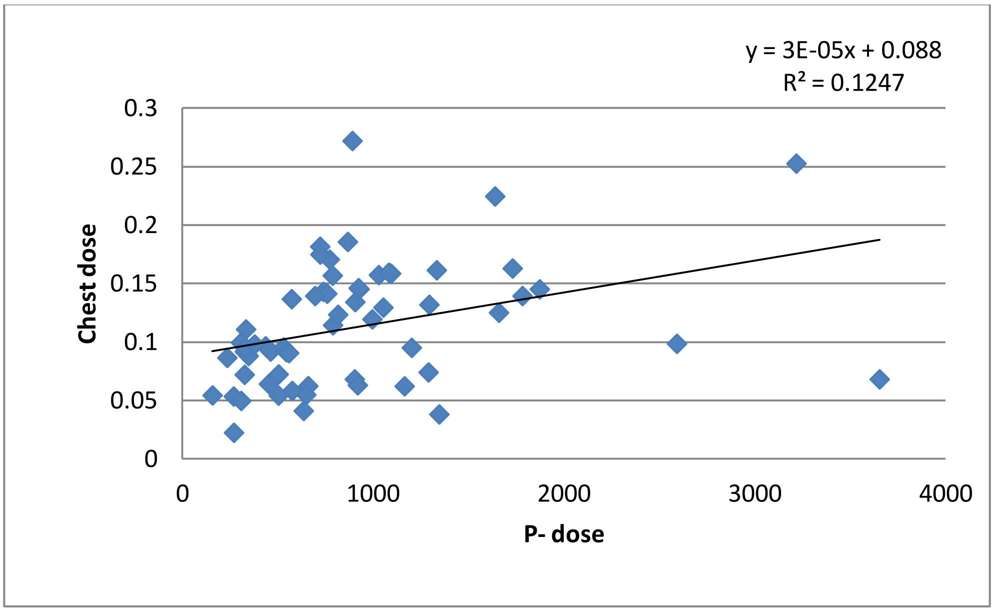


Figure: 5-14: Correlation between patient dose and operator chest dose

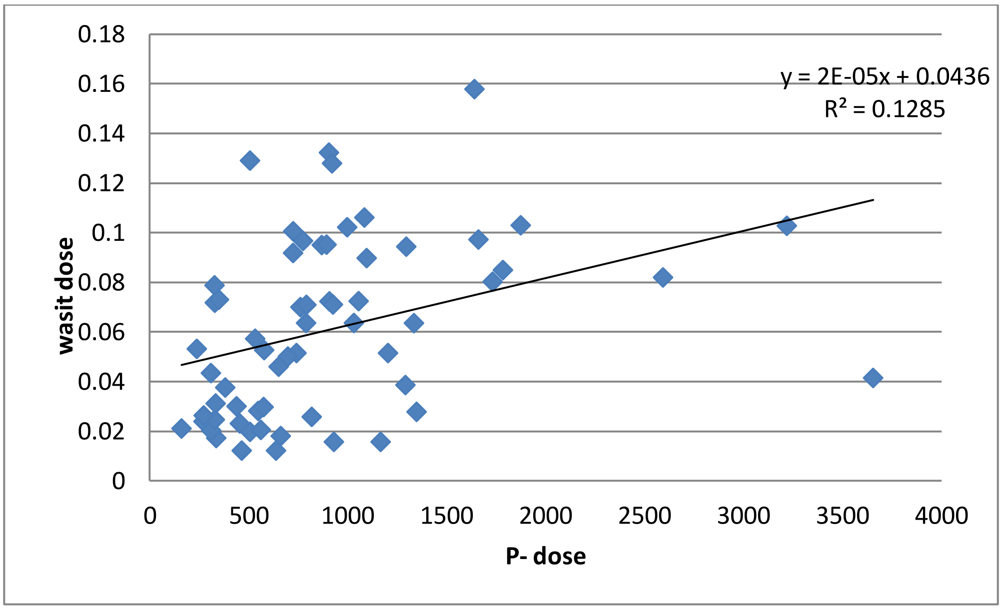


Figure- 5-15: Correlation between patient dose and operator waist dose

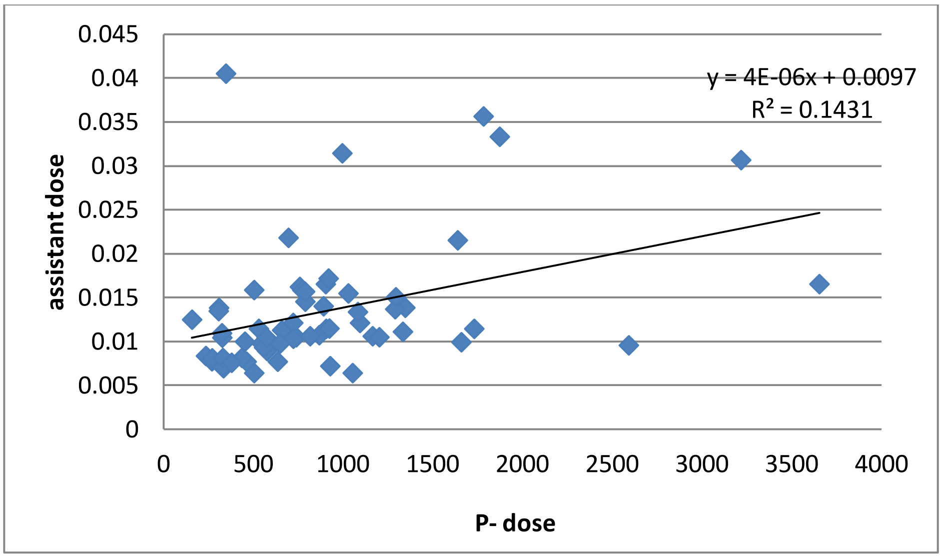


Figure- 5-16: Correlation between patient dose and assistant dose

They are a correlation was found between fluoroscopy time and patient dose (R^2=0.686) are shown in the figure 5-17.

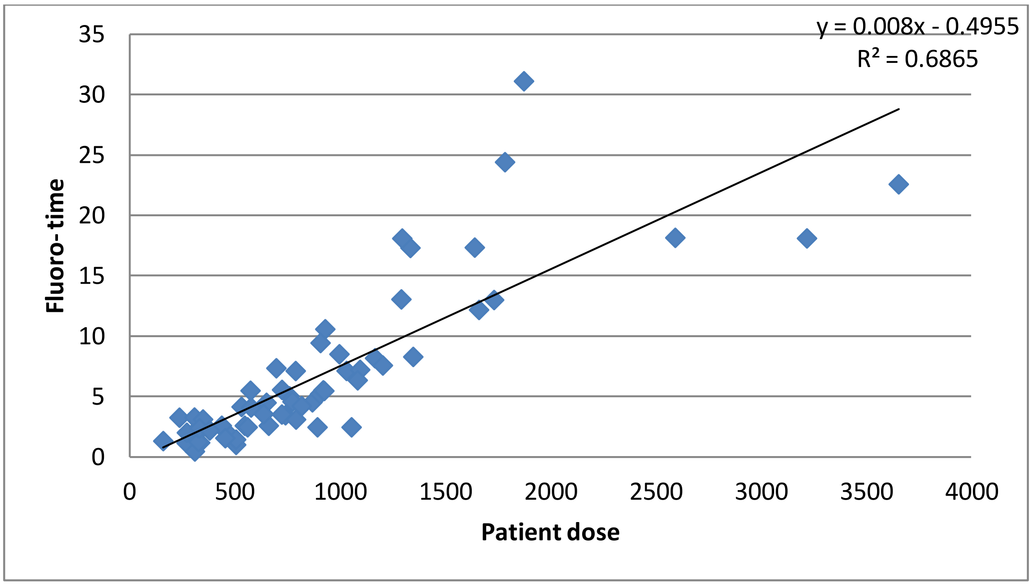


Figure- 5-17: correlation between patient dose and fluoroscopy time

5-2: Conclusion:

Patient and staff dose measurement is of prime importance and protection shield optimize the radiation dose. Patient dose was measured in two cardiac clinical hospitals using dose area product (DAP) meters. Were studies in two groups, coronary angiography (CA) and percutaneous coronary interventions (PCI).The mean DAP values were found 917.07±68.17mGy/cm^{2} range from 642.69±30.02mGy/cm^{2} for CA procedure to 1783.25±81.56mGy/cm^{2} for PCI procedure. The effective dose for the same procedures were calculated a suing (DAP) to effective dose conversion factor of 7.191mSv per procedure, there were 6.427mSv for CA and 17.833mSv for PCI per procedure. These values are compared with those found relatively lower than literature previous studies.

The radiation absorbed doses for staff to the different organs during interventional catheterization procedures was studies in two group, diagnostic procedure (CA) and therapeutic (PCI) procedure at three organs (hand, chest and waist) for main operator and chest for the assistant operator using calibrated TLDs. Based on the obtained it could be calculated that, the mean radiation doses values received to the different organs by main operator during CA and PCI procedures with acceptable limits is the tight of current workload. Measurement of ambient exposure rate during procedures is useful for staff protection because it guides them to change their position to safe areas in a manner to minimize radiation exposure. Further radiation dose reduction could be as low as reasonable achievable (ALARA) by using mini c- arm x- ray machine, staff training is crucial and calibration protection equipments in spite of the low radiation doses during selected procedures, no matter other procedures may carry risk to both patient and staff. The hands of the main operator were most to be directly exposure to ionizing radiation during interventional fluoroscopic in the case of bad practice, and the highest radiation dose received for cardiologist hands. The doses was received to the assistant operator it is lower than main operator because the main operator between ionizing radiation source and assistant during procedure.

Radiation doses for staff organs during procedure are lower than cardiologic procedures in literature previous, lead apron and shield has significant role in radiation dose reduction, PCI procedure increase radiation scattered to personnel in the operator room than CA procedure. Scatter dose rates increasing depended with patient dose rates for all the typical BMI of patient and experimental correlation factor per procedure.

A correlation was found to exist between the BMI of patient and the tube potential automatically selected. A strong correlation between patient dose values and fluoroscopy time, the number of cine frames also was found.

In this study the entrance surface does (ESD) on the patient and staff positions body wall less than in similar literature studies.

5-3: Recommendations:

The followings measures are important in patient dose and staff reduction:
- Well training continuous monitoring rich knowledge about hazard among (IC) is starting steps to reduce radiation risk.

- Continuous quality control test for equipment and x- ray C-arm machines is a key in radiation optimization for both patient and staff.

- Special case must be taken during cardiac interventional procedure by using lowest possible radiation dose without compromising the finding.

- Continually review and update the technique standards used by cardiology professionals.

- Continuous education for staff (main operator and assistant) is highly recommended in order to reduce patient dose.

- Minimize the use fluoroscopy and use low fluoroscopy modes (for example pulsed fluoroscopy) when possible.

- Collimation of the radiation field (and generally all other factors reduction patient dose) decreases the level scattered radiation dose.

- Increase distance from the radiation source to target in the catheterization laboratory. Working more than (100cm) from the centre instead of (40cm) can decrease scattered dose to approximately a quarter of the original dose.

Reference:

- A. Niroomand-Rad. Radiological Protection of Patients - Iran. J. Radiat Res, 2003; 1(3):125-131. Georgetown university Medical center, Washington D.C, USA 2003.

- A.Trianni,R. Padovani, C .Foti, E. Caranolini,H. Toh, G. Bernardi and A. proclemer. Dose to cardiologists in Hemodynamic and electrophysiology cardiac interventional procedures. Radiation Protection Dosimetry, 2005 : Vol 117, NO. 1-3 pp 111- 115.

- Abdelmoneim Suleiman, Georgios Paroutoglou, Andreas Kapsoritakis, Anargeyros Kapatenakis, Spiros potamianos, Marianna Vlychou, Kiki Theodorou . Reduction of Radiation to Patients and Staff during Endoscopic Retrograde Cholangiopancreatography. The Saudi Journal of Gastroenterology University Hospital of Larissa Greece 2011.

- Ali Mohamed. Optimization of Radiation Dose in Multisices CT Scan Examination. M.Sc study. Sudan University of Science and Technology - Sudan 2011.

- Andrew Ertel, Jefferey Nadelson, Adhir R. Shroff, Ranya Sweis,Dean Ferrera, and Mlodanl.Uidovich[1].Radiation dose reduction during radial cardiac catheterization evaluation of dedicated radial angiography absorption shielding drape. International Scholarly Research Network (ISRN) cardiology.Vol-2012 Article ID769167, 5.

- Antonia Savva . Personal TLD monitors their calibration and response. M.Sc study Faculty of Engineering and Physical sciences. University of Surrey 2010.

- B F WALL, BSc and D HART, PhD. What is Risk Potential Assessment.The British Journal of Radiology 70(1997), 437-439 British Institute of Radiology 1997.

- Badreldin M. A. Elhag, Hiba Omer, Abdelmoneim Suleiman. Estimation of pediatric radiation doses in intravenous urography. Asian Journal of Medical and Clinical Sciences 2012.

- Badreldin Mohamed. Measurement of Radiation Dose and Risk Estimation in Paediatric Radiology PHD study. Sudan University of Science and Technology. Sudan 2012.

- Brian D, Giordano, Judith F, Baumhauer, Thomas L, Morg and Glinn R. Rechtine. Patient and surgeon radiation exposure comparison of standard and mini C- arm fluoroscopy.J Bone Joint Sury Am.2009, 91: 297- 304.

- Brian L. Badman, Lynn Rill, Bradley Butkoich, Manuel Arreola and Robert A. Vander Gried. Radiation exposure with use of Mini- C- arm for routine orthopedic imaging procedures - Journal of Bone and Joint surgery. University of Colorado 2005.

- C. Foti, R, Padovani, A. Trianni. Staff Dosimetry In Interventional Cardiology Survey On Level Of Exposure- Radiation Protection Dosimetry (2008), vol, 129, No.1-3, pp. 100-103.

- C.K. Ying& S. Kandaiya. EDR2 Film for Skin Dose Measurement in Coronary Angiography .Asian Malaysiana 41(!) 2012.133- 140.

- Cardiac Catheterization Equipment Performance - Report of task Group #17 NO.70 Diagnostic X- ray imaging committee .American Association of physicists in medicine by medical physics 2001.

- Chris J. Huyskens and Willy A. Hummel. Radiation Exposure in Interventional Cardiology Eindhoven University of technology Netherlands 1993.

- Competency Training Requirement for the Area of Focused Competence in Interventional Cardiology. Royal College of Physications and Surgeons of Canada 2012.

- Daniela Kroutilikova, Josef Novotry, Libor Judas. Thermoluminescent dosimeters (TLD) quality assurance network in the Czech Republic- Radiotherapy and oncology 66(2003) 235-244.

- Dr Amy Barrington de Gonzalez, Sarah Darby. Risk of cancer from diagnostic X- ray estimate for UK and 14 other countries – University of Oxford 2004.

- Dr. Peter Joseph Hubert Kicken. Radiation dosimetry in vascular radiology: Organ effective dose to patient and staff .Netherland 2009.

- E Vano' ,PhD, L Gonzalez, PhD, J TEN, BSc, J Mfernandez, BSc, E GuIBElalde, PhD and C Macaya, PhD, MD- Skin dose and area product values for interventional cardiology procedures- The British Journal of Radiology , 74(2001) 48-55.

- E vano, PHD, L Gonzalez, PHD, E Guibelalde, J M fernandez, BSc and J iten, BSc . Radiation exposure to medical staff in interventional and cardiac radiology .The British Journal of Radiology, 71 (1998), 954- 960.

- E Vano, PhD, MD L Gonzalez, PhD, J Mfernandez, B Sc F Alfonso, PhD, and C macaya, PhD, MD . Occupational radiation dose in interventional cardiology a-15-year follow- up- The British Journal of Radiology, 74(2001), 48-55.

- Eleni- Theano Samara, Abbas Aroua, Francois Oswald Bochud, Alain Delabays, Jean- Pascal Laedermann, and Francis Robert Vedun. Patient Radiation Risk in Interventional Cardiology.OMICS Journal of Radiology Switzerland 2012, 1:2.

- Eliseo Vano , Carlos Ubeda , Fernando Leyto, Patricia Miranda , Luciano Gonzalez . Staff radiation doses in interventional cardiology : correlation with patient exposure radiation . Department Complutense University of Madrid 2009.

- Eliseo Vano, Carlos Ubeda, Fernando leyton, Paticia Miranda, Luciano Gonzalez. Staff radiation dose in interventional cardiology: correlation with patient exposure. Pediatr Cadio 2008.

- Entisar Omer . Measurement of Pediatric Dose in CT Urography Convent M.Sc thesis - Sudan University of Science and Technology .Sudan 2011.

- Evolution of ICRP Recommendations 1977, 1990 and 2007.

- F. R.A. Lima, H.J.Khoury , Hazin and L,P. Luz, Av. Luiz Freire, 1000-50740-540 Recife Brasil. Dose to operating staff during Interventional cardiology Procedures - Department de Energia Nuclear. UFPE Brazil T.23-4, p:7-41.

- F.Bouzarjomehri[1] and V.Tsapki[2].Patient dose values during interventional cardiology examinations in Yazd hospital Iran.Iran. J. Radiation - Res, 2009,6(4). 167- 172.

- Florin Ceusan- Scattered and Leakage Radiation during Radiotherapy Treatment 2004.

- G.Tavernarakis,Michael I.Molfetas. Patient Dose in Cardiac Radiology.Hellenic J cardiology 2009; 50:17-25.

- Gerritjan Kuipers and Xandra L. Velders.- Effsctive dose to staff from interventional procedures: estimations from single and double dosimetry-Radiation Protection Dosimetry(2009) vol. 136, No. 2, PP.95-100, AMC Meibergdreef 9, postbus 226600,11oo DD Amsterdam -Netherlands 2009.

- Gerritjan Kuipers, Xandra L.Velders DDS,PHD, Jan J. Piek, PHD . personal dosimetry in interventional cardiology in period 1999- 2004- Department of cardiology, Academic Medical Center (AMC) Amsterdam 2011.

- GH. Fallah Mohammadi, M.Vahabi Moghadam, M. Ghanbar Moghadam. Staff dose assessment from coronary angiography. International Journal of Radiation Research 2014.

- Glenfield Hospital, Groby Road Leicester LE3 9QP, UK. Radiation Protection in Cardiac and Interventional Procedures University Hospital 0f Leicester 2004.

- H. Joda, Abdelmoneim A. Suleiman, Mohamed Y.Hamadelneel . Radiation dose measurement for staff during cardiac catheterization . Sudan Medical monitor - April 2010 vol.5 (2): 103- 106.

- H. Osman, A. Elzaki, A. Sulieman,I.I.Sulieman,A.K. Sam.Evaluation of staff and ambient exposure during orthopedic procedures. Asian Journal of Medical and Clinical Sciences 2012.

- H.Osman, A. Suleiman, I.I Suleiman, A .K. Sam. Radiation Dose Measurements in Routine X- ray Examinations. Tenth Radiation Physics protection conference November 2010 . Naser City- Egybt .

- Henri Justino. The ALARA concept in pediatric cardiac catheterization: techniques and tactics for managing radiation dose - Pediatr Radiol (2006) 36

- Herman Cember, Thomas E.Johnson- Health Physics Colorado University 2009.

- Hiba H.Joda,Abdelmoneim A.Sulieman,Mohamed Y.Hamadelneel. Radiation dose measurement for staff during cardiac catheterization Sudan Medical Monitor 2010 Vol.5 No.2 P 103- 106.

- Hiba Hashim. Radiation Dose Measurement for Patient and Staff During Cardiac Catheterization M.Sc study- Sudan University of Science and Technology - Sudan 2009.

- Hodder Arnold - Clarks positioning in radiotherapy 2005- London. IAEA. Patient dose optimization in Fluoroscopically Guided Interventional Procedures .Vienna 2010.

- Ibrahim I. Suleiman, J.S. Mohamed, M.A.khalifa, and A.M.Ahmed- Evaluation of Radiation doses form Pediatric Chest X-ray Examination in Some Hospital in

Khartoum Area .Radiation Safety Institute, Sudan Atomic Energy commission Khartoum, Sudan 2008.

- ICRP -Publication XXX- Patient and staff radiological protection in cardiology 2011.

- Instant conversion for units of radiation on the web since 1996. International Commission on Radiation Protection Publication (1990) recommendations of International on Radiological Protection Publication 60(Pergamum Press).

- International Atomic Energy Agency. Basic radiation physics- Vienna - ISBN 92-0-107304-6.

- International Atomic Energy Agency. Radiological protection of patients in diagnostic and interventional radiology, nuclear medicine and radiotherapy – Vienna, Austria march 2001.

- Interventional Commission on Radiological Protection Recommendation of the ICRP publication 60- oxford: pregame 1991.

- J. Domienik, S.papierz,J. Jankowski, J.Z. Peruga . Patient doses in interventional cardiology procedures- Department of Cardiology Medical University of Lodz Poland- 2007.

- Jun-Jack Cheng. Health Effects of Medical Radiation on cardiologists who Perform Cardiac Catheterization. J Chin Med Assoc 2010 Vol 73 No 5.

- Jun-Jack cheng. Health Effects of Medical Radiation on Cardiologists Who Cardiac Catheterization. College of Medicine, Taiwan Medical University Taiwan 2010.

- Lin, PhD. Radiation safety program for the cardiac catheterization laboratory. Catheterization and cardiovascular interventions: 00: 000- 000(2011).

- Maria Boutros . Radiation assessment to patient and staff from new lexxos bone densitometer -M.Sc study -school of medicine Kings College London 2003.

- Maria Grazia Andreassi, Angelo Cioppa, Nicoletta Botta, Gordana Joksic .Somatic DNA damage in interventional cardiologists: a case control study . The FASEB Journal expresses article 10:1096/ Fj.04-3287 Fje. 2005.

- Maria Grazia Andreassi, Angelo Gioppa, Nicoletto Botto,Gordano Joksic, Samantha Mofredi, Chiara Federici,Modrag Ostojic, Paolo Rubina and Eugene Picano . Semantic DNA damage in interventional cardiologist: a case control study. The Faseb Journal express art march 2006.

- Marta Hernanz- Schulman, Marilyn J. Goske, Ishtiaq H. Bercha, Keith J. Strauss. Pause and pulse: ten steps that help manage radiation dose during pediatric fluoroscopy. American Roentgen Ray Society 2011.

- Micha Maeder, R. Verdun, Jean-Christophe Stauffer, Peter Ammann, Hans Rickli. Radiation exposure and radiation protection in interventional cardiology Kardiovaskulare Medizin 2005:8:124-132.

- Midshipman Jeffrey H. Dormo. Optical calibration of TLD Readers - United States Naval Academy 2003.

- MM Rehani, PHD. The LAEA,S activities on radiation protection in interventional cardiology International Atomic Energy Agency Vienna Austria 2007. 31.

- Mr. Murari Sharma, Mr. Peter V. O, Connell. Radiation Dosimetry- Interventional Atomic Energy Agency- Vienna- ISBN 92-0-107304-5. 2004.

- N. Todorovic, I.Bikit, J.Nikolov, S. Forkapic, D. Mrdja, S.Ttodorovic- Workplace Monitoring During Interventional Cardiology Procedures - World Academy of Science Engineering and Technology 76 (2o11) Faculty of science, University of Novi Sad 2011 .

- Nazar Alhassan . Measurement of Radiation dose in Intravenous Urography M.Sc thesis. Sudan University of Science and Technology - Sudan 2012.

- Noor . Ul. Hadi, Adnan Mahmood Gul, Fazal- Ghofoor, Syed Tahir Shah, Abdul Wali, Syed Javed Shah, Syed Sadig Shah, Saeed Ali, Rahman Said, Kashifulla, Amber Ashraf, Mohammad Hafizullah. Radiation Exposure In Different Cardiac Catheterization Procedures In Cathlab. JAyud Med Coll Abbottabad **2013,25(3-5).**

- Nuclear Medicine and Diagnostic Radiology in Institute of nuclear medicine and technology at Elgezira- report.

- Nuclear Regulatory Commission. NRC Regulation 2007.

- Olivier Bar, Carlo Maccia , Pierre Pages, Didier Blanchard,- Multicentre Survey of Patient Exposure to Ionizing Radiation During Interventional Cardiology Procedures in France . Europe Edition 2008.

- Omer Osman. Effective dose estimation during Pediatric Chest x- ray Radiography M.Sc study . Sudan University of Science and Technology - Sudan 2012.

- OWE Morrish, BSc, and Kegoldstone, MSc, - An investigation into patient and staff doses from X-ray angiography during coronary interventional procedures. British Journal of Radiology 81(2008) 35-45

- P P Dendy , PhD . radiation risk in interventional radiology- the British Journal of Radiology, 81(2008), 1-7.

- Ph. R. Ttueb, A. Aroua, A.Stuessei, R.Samara, R.Trier, F.R. Verdun, F. Bochud, W.Zeller. Diagnostic Reference Levels in Cardiology Interventional radiology . DRL Cardio and Fluoro Wc 2009.

- Qydis Qstbys Lie, Gudrun Uthaug Paulsem and Tor Wqhni. Assessment of effective dose and the dose lens of the eye for the interventional cardiologist Norwegian Radiation Protection Dosimetry (2008) vol.132, No.3: p 313-316.

- Radiation Safety in the practice of cardiology - 1998:892-913 By the American college of cardiology Writing Group Member published by Elsvier Science Inc.

- Raphael Kluy, James J.Mccarthy, Robert E. Eilert. The use of two C- arm technique in the treatment of slipped capital Femoral Epiphysis. Colorado 2004.

- Rasha Mohammed. Radiation dose measurements and risk estimation for patients and staff during cardiac catheterization-M.Sc study- University of Khartoum-Sudan 2011.

- Sandra Ann Hopkins calculation verification and monitoring of patient dose in diagnostic and interventional cardiology- M.Sc study - University of Surrey 2010.

- Sophie Jacob, Alexandre Bertrand, Marie-Odile Bernier- Occupational Cataracrts and Lens Opacities in interventional cardiology-Institute for Radiological Protection and Nuclear Safety, BP17, 92262 Fontenay- aux- Roses Cedex France 2010.

- Sornjarod Oonsiri MSc. Radiation Dose to Medical Staff in Interventional Radiology J Med Assoc Thai 2007, 90(4): 823- 828.

- Stephen Balter Douglas W. Fletcher, Hsin M. Kuan, Donald Miller, Detlev Richter, Hannes Seissl, Thomas B. Shope Jr. Techniques to estimate radiation dose to skin during fluoroscopy gided procedures.-Skin Dose Measurements AAPM July 2002 p : 1- 10.

- Thanyain K. Basic radiological physics lardson publishers ltd 2001.p 207- 209.

- The Recommendations of International Commission on Radiological Protection 2012 IS BN 978- 7020- 3048- 2.

- The Recommendations of International commission Radiation Protection 1990 IS BN 978-0- 08- 041144- 6.

- Unscear. Source and Effects of ionizing Radiation 2008. (Suppl 2): 146- 153.

-J.Domienik,S.Papierz,J.Jankowski, J. Z. Peruga - Patient dose in interventional cardiology procedures . Nofer Institute of Occupational Medicine in lodz Poland-presenting author, E- mail: jdom@ imp. Lodz.pl.

-Jrwilliams, MSc, FIPEM - The interdependence of staff and patient doses in interventional radiology The British journal radiology 70(1997), 498- 503, British Institute of Radiology 1997.

-S.Mehdizadeh, M A. Owrangi, Sh. Derakhshan . Cardiologist hand dose measurement in interventional radiology . Asian Journal vol.21 November 2007.

-U.S. Department of energy Office of worker safety and health policy (HS-11) Radiation detection instrumentation at the department of energy Radiation Detection and Measurement. Second Edition New York 1989.

-Verdum Francis R., Aroua, Abbas, samara Eleni. Protection of the patient and the staff from Radiation Exposure during fluoroscopy guided procedures in cardiology- lausnne University hospital Switzerland 2011.