Sudan University of Science and Technology

College of Graduate Studies and Scientific Research

Evaluation of Patients and Staff Radiation Doses in Intervention Radiology

تقدير الجرعة الاشعاعية للمرضى والعاملين في تخصص الأشعة التدخلية

A thesis submitted in fulfillment for the requirements

Of PhD degree in Medical Physics

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2016

قال تعالى:

﴿ قُلْ سِيرُوا فِي الْأَرْضِ فَانْظُرُوا كَيْفَ بَدَأَ الْخَلْقَ ثُمَّ اللَّهُ يُنْشِئُ النَّشْأَةَ الْآَخِرَةَ إِنَّ اللَّهَ عَلَى كُلِّ شَيْءٍ قَدِيرٌ﴾

العنكبوت الايه 20

Dedication

To my mother

To my love

To my friends, And to all my family

Acknowledgements

I would like to send my deepest gratitude to Dr. **Abdelmoneim Adam Mohamed Sulieman** for his support and guidance. Without his help this work could not have been accomplished.

I also would like to thank Dr. Mohamed Elfadel. My thanks also go to royal care center, khartoumteaching hospital, Elmeknimer university hospital and Kuwait special hospital staff for their help.

Deep thanks to my friend Finally, I would like to sincerely thank my family for their consistent mental support.

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ABBREVIATIONS

Symbols	Item
3D	Three dimension
AVM	Arterio venous Malformations
BMI	body mass index
BMI	Body mass index
BSF	the backscatter factor
CD	Cumulated Dose
Cine	cine angiography
CT	Computed Tomography
DAP	dose area product
DCS	Dynamic Cannula screw
DHS	Dynamic Hip screw
DHS	Dynamic hip screw
DRLs	Diagnostic Reference Levels
DSA	Digital subtraction angiography.
E	effective dose
E.N.U.H	ElmekNimer University Hospital
EPS	electrophysiological studies
ERCP	Endoscopic Retrograde Cholangiopancreatography
ESD	Entrance Surface Dose
EVAR	Endovascular Aneurysm Repair
F.t	Fluoroscopy time
FFD	Focal to film Distance
FSD	Focal to Skin Distance
H	Equivalent dose
HSG	Hysteron SalpingGraphy
IA	Image Amplifier
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
IR	Intervention Radiology

ABBREVIATIONS

K.S.C	Kuwait Special Center
K.T.H	Khartoum Teaching Hospital

KERMA	Kinetic Energy Released per unit Mass of Air
kVp	kilovolt peak
LPDF	Lock plate distal femur
MII	Mobile Image Intensifiers
MRI	Magnetic Resonance Image
Pa_0	Pacemaker type one
Pa_1	Pacemaker type two
Pa_2	Pacemaker type three
PAD	peripheral arterial disease
PCI	percutaneous coronary intervention
PSD	Peak skin dose
PTCA	Percutaneous Transluminal Coronary Angioplasty
QC	Quality control
R.C.C	Royal Care Center
RF	radiofrequency
RP	Radiation Protection
T_{dose}	Total Dose
TIPS	Transjugular Intrahepatic Portosystemic Shunt
UFE	UFE Uterine Fibroid Embolization
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
VIR	Vascular Intervention Radiology
W_R	Radiation weighting factor
W_T	weighting factor for some organ or tissue
XRII	X-ray image intensifier

Abstract

Interventional radiology (abbreviated IR or VIR for Vascular and Interventional Radiology, also referred to as Surgical Radiology) is a medical sub-specialty of radiology which utilizes minimally-invasive image-guided procedures to diagnose and treat diseases in nearly every organ system.

This study intends to evaluate the patients and staff radiation doses in intervention radiology for four procedures; vascular, pacemaker, brain and orthopedic in Sudan to 826 adults patients and 44 staff. they were exposed in four hospitals equipped with C-Arm imaging modalities, 301

patients and 15 staff are exposure in Khartoum Teaching Hospital, 100 patients and 8 staff are exposure in Royal Care Hospital, 201 patients and 7 staff are exposure in Kuwait special Hospital and 224 patients and 14 staff are exposure in Elmek Nimer University Hospital.

The mean Kv for vascular, pacemaker, brain and orthopedic intervention were 77.16, 76.41, 70.0 and 63.62 respectively. While the mean mAs for the four procedures were 1344.32, 291.25, 530.75 and 600 respectively. Also the mean ESD for the four procedures were 73.69, 33.73, 26.53 and 1.22 respectively while the mean DAP for the four procedures were 17.39, 4.31, 11.63 and 0.63 G. Cm^2respectively.The mean doses of staff that exposed in vascular intervention procedures were 26.12, 13.04, 12.9 and 7.15 µsVr for physician, assistant, nurse and technician respectively. The mean doses of staff that exposed in brain intervention procedures were 21.05, 18.09, 15.98, and 16.05 µsVr for physician, assistant, nurse and technician respectively. The mean doses of staff that exposed in pacemaker intervention radiology procedures were 1.35, 1.08, 0.91 and 0.13 µsVr for physician, assistant, nurse and technician respectively. The mean doses of staff that exposed in orthopedic intervention radiology procedures were 7.15, 0.13, 0.05 and 0.05 µsVr for physician, assistant, nurse and technician respectively.

ESD, DAP were the highest in vascular intervention radiology procedure this because of using high Kv, high mAs and long duration as measured, also the physician is the highest radiation dose one, Vascular intervention radiology which is highest procedure while in orthopedic intervention radiology is lowest one which are same as a major pervious studies .

In this study correlations were done; between entrance skin dose ESD (mGy) compared to tube potential kVp (kV), duration of the procedure (minute) and dose area product DAP (mGy.Cm^2); $R^2$are 0.79, 0.30 and 0.51 respectively which are good in kVp and DAP and weakly in duration of the procedure. Also it is found that the correlation between ESD and kVp increased by 3.93 unit per 1 kVp unit while ESD increased by 3.83 unit per 1 DAP unit.

From all this studies it found that factors affecting dose to patient and staff are fluoroscopy time, number of frames, field size, technical characteristics of radiation equipment, patient size and examination type and operation mode

Patients and staff radiation doses vary widely among the different interventional radiology procedures but also among published studies. Discrepancies of the derived results are patient, procedure, physician, and fluoroscopic equipment related. Nevertheless, IR procedures can subject patients to considerable radiation doses and efforts to minimize patient exposure should always be undertaken. So advices the staff to use minimum Kv, minimum mAs, and minimum duration of the procedures as low as possible. Minimize the use of fluoroscopy and using low fluoroscopy modes when possible. An experience one in any field must be found in the interventional radiology to minimize the radiation dose. More studies in intervention radiology.

ملخص البحث

الأشعة التداخلية (تختصر IR أو VIR للأوعية الدموية والأشعة التداخلية، ويشار إليها بجراحة الأشعة أيضا) هو فرع من الطب يختص بالأشعة التي تستخدم عمليات – اختراق صورة – توجيه دقيق لتشخيص وعلاج الأمراض في كل نظام الجهاز تقريبا.

أيضا، عزمت هذه الراسة لتقييم الجرعات الإشعاعية للمرضى والموظفين في الأشعة التداخلية لأربعة عمليات هي: الأوعية الدموية و جهاز تنظيم ضربات القلب والدماغ والعظام في أربعة مستشفيات في السودان لعدد 826 من المرضى البالغين و 44 عاملاً تعرضوا للاشعة 301 مريض و 15 عامل في مستشفي الخرطوم التعليمي و 100 مريض و 8 عاملين

في مستشفي رويال كير و 201 مريض و 7 عاملين في المستشفي الكويتي التخصصي و 224 مريض و 14 عامل في مستشفي المك نمر الجامعي.

متوسط الفولتية للاوعية الدموية وجهاز تنظيم ضربات القلب و المخ والعظام 77.16 و 76.41 و 70.0 و 63.62 علي التوالي بينما متوسط التيار لهذه العمليات 1344.32 و 291.25 و 530.75 و 600 علي التوالي. ايضاً جرعة الجلد السطحية لهذه العمليات 73.69 و 33.73 و 26.53 و 1.22 علي التوالي بينما جرعة المنطقة 17.39 و 4.31 و 11.63 و 0.63 جري *سنتمتر ^{2} علي التوالي .

متوسط الجرعة التي تعرض لها العاملين في عمليات تصوير الاوعية التداخلية 26.12 و 13.04 و 12.9 و 7.15 للطبيب و المساعد والممرض والتقني علي التوالي في حين متوسط الجرعة التي تعرض لها العاملين في عمليات تصويرالمخ بالأشعة التداخلية 21.05 و 18.09 و 15.98 و 16.05 للطبيب و المساعد والممرض والتقني علي التوالي بينما متوسط الجرعة التي تعرض لها العاملين في عمليات تصويرجهاز تنظيم ضربات القلب بالأشعة التداخلية 1.35 و 1.08 و 0.91 و 0.13 للطبيب و المساعد والممرض والتقني علي التوالي ايضا متوسط الجرعة التي تعرض لها العاملين في عمليات تصوير العظام بالأشعة التداخلية 7.15 و 0.13 و 0.05 و 0.05 للطبيب و المساعد والممرض والتقني علي التوالي.

وجد أن جرعة الجلد السطحية وجرعة المنطقة هي الأعلي في عملية الأوعية للأشعة التداخلية نتيجة لإستخدام فولتية عالية وتيار عالي وزمن تشعيع أكبر ايضاً وجد أن جرعة الطبيب هي الأعلي نسبة لإتصاله بالمريض مباشرة وهي مشابهة لمعظم الراسات السابقة .

اجريت العلاقة بين جرعة الجلد السطحية بالملي جري مقارنة بافولتية ومدة العملية بالدقيقة وجرعة المنطقة بملي جري مضروب في السنتمتر المربع حيث وجدت العلاقة (R^2) لهم 0.79 و 0.30 و 0.51 علي التوالي وهي قوية للفولتية وجرعة المنطقة وضعيفة مع مدة العملية. ايضاً وجد أن العلاقة بين ESD والفولتية تزداد 3.93 وحدة لوحدة الفولتية في حين تزداد ESD 3.83 وحدة لوحدة DAP من كل هذه الراسات وجد أن العوامل التي تؤثر على جرعة المريض والعاملين زمن التشعيع ، وعدد الصور ، وحجم الحقل، والخصائص الفنية لمعدات الإشعاع، وحجم المريض ونوع الفحص ونوع العملية.

جرعات المرضى والعاملين الإشعاعية تختلف على نطاق واسع بين مختلف عمليات الأشعة التدخلية أيضا بين الراسات المنشورة. اختلاف النتائج مستمد من المريض والعملية، و الطبيب، و ومعدات الأشعة ذات الصلة. ومع ذلك، يمكن لعمليات الأشعة التدخلية ان تعرض المرضى لجرعات إشعاع كبيرة لذلك لابد من تقليل التعرض للحد من هذه الجرعات.

لذلك ينصح العاملين على تقليل الفولتية والتيار، وتقليل المدة الزمنية للعملية لأقل مستوى ممكن. التقليل من استخدام الأشعة الفسفورية واستخدامها بصورة قليلة عندما يكون ذلك ممكنا. لابد من وجود خبير في الأشعة التداخلية لتقليل جرعة الاشعاع و عمل مزيد من الراسات في الأشعة التدخلية .

Chapter one: Introduction

Chapter one: Introduction

1.1 Interventional radiology

Interventional radiology (abbreviated IR or VIR for Vascular and Interventional Radiology, also referred to as Surgical Radiology) is a medical sub-specialty of radiology which utilizes minimally-invasive image-guided procedures to diagnose and treat diseases in nearly every organ system. The concept behind interventional radiology is to diagnose and treat patients using the

least invasive techniques currently available in order to minimize risk to the patient and improve health outcomes. As the inventors of angioplasty and the catheter-delivered stent, interventional radiologists pioneered modern minimally-invasive medicine. Using X-ray fluoroscopy, CT, ultrasound, MRI, and other imaging modalities, interventional radiologists obtain images which are then used to direct interventional instruments throughout the body. These procedures are usually performed using needles and narrow tubes called catheters, rather than by making large incisions into the body as in traditional surgery. Many conditions that once required surgery can now be treated non-surgically by interventional radiologists. By minimizing the physical trauma to the patient, peripheral interventions can reduce infection rates and recovery time, as well as shorten hospital stays.

(http://www.wiki/Interventional_radiology).

1.2 Staff and patient exposure

Ionizing radiation is a workplace hazard that cannot be detected by the human senses. The cardiovascular laboratory or cathlab is one such place where ionizing radiation is much in use. The cathlab is a closed atmosphere where the working staff (i.e. cardiologists, cardiac technicians, radiographers, nurses and trainees) is at a potential risk to radiation exposure almost on a daily basis. Compared to other departments (radiology, urology, operating rooms, etc.) that also use x-ray equipment, the cardiac cathlab is generally considered an area where exposure to radiation is particularly high. Factors such as the configuration of the x-ray equipment, the number of cases per day, and the often long period of screening required for a study, contribute to this relatively high level of exposure and monitoring results for staff members in the cathlab who wear single badges at the collar outside their lead aprons are generally amongst the highestin the hospital.

Exposure rates exceeding 7.14 Gy/hr(i.e. 5 sievert/hr) in the cath lab have been reported and interventional procedures such as percutaneous coronary intervention (PCI) and electrophysiological studies (EPS) pacing result in the highest radiation exposure to patients and staff . (KUON,(2005).

Radiation in the cathlab is generated using two different modes: fluoroscopy or cine angiography (cine). Fluoroscopy is used for catheter placement and involves 95% of the total x-ray operation time but only causes 40% of the total radiation exposure to staff and patients. This is due to pulsed screening that reduces exposure dose. Cine is used to acquire diagnostic images and to generate a permanent record of the procedure and, although representing only 5% of the total x-ray tube operation time, 60% of the total radiation exposure to staff and patients occur during cine. This is primarily due to use of relatively high dose rapid sequence screening required to record onto film. Significant reductions in exposure can be realized by being aware of when cine is will be used and applying radiation safety measures accordingly. It is important to effectively measure radiation doses acquired by cathlab personnel but exact dosage quantities are difficult to derive due to the non-uniformity of irradiation and differences in X-ray intensity as well as the relatively low energies generated by modern equipment. Therefore the International Commission on Radiological Protection (ICRP) recommend the use of effective dose (E) to evaluate the effects of partial exposure and relate this to the risk of equivalent whole body exposure. It is expressed in Sievert units (Sv) (1Gray unit = 0.7 sievert unit). Modern cardiac interventional procedures (coronary angiography and PCI) produce effective doses of 4 to 21 mSv and 9 to 29 mSv respectively and are therefore relatively high (1 mSv is the equivalent of approximately 10 chest x-rays).(Rehani, (2006) .

The intensity of the biological effect of X-rays is dependent on the absorbed dose (total radiation energy per unit mass) of sensitive tissue and is expressed in gray units (Gy). The average dose per procedure for the cardiologist is estimated at 0.05 mGy. To allow better comparison of patient and staff doses this value can be expressed as the dose area product (DAP). The DAP is calculated as the product of dose in air in a given plane and the area of the irradiating beam and is independent of the distance from the x-ray source. Coronary angiography and PCI produce mean-patient DAPs in the range 20 to 106 Gy.cm2 and 44 to 143 Gy.cm2 respectively. (KUON, E., et al. (2005).

1.3 Dose Level

The purpose of it is to set Diagnostic Reference Levels (DRLs) in interventional radiology by means of dose area product (DAP) measurements and the grouping of homogeneous procedures,

and to quantify the associated errors in the DRL estimates. To evaluate the Mean Effective Doses per single procedure and results of dose level is the main features of DAP distributions are long high-dose tails, indicating asymmetric distributions, together with a large interquartile range. Rounded third-quartile values of DAP distributions showed a large range in the procedures taken into consideration. Values of 147, 198, 338 Gy cm^2 were obtained for supra-aortic angiography, cerebral angiography and embolization. Values of 86-101 and 459-438 Gy cm^2 were obtained for diagnostic and interventional vascular procedures on the lower limbs and on the abdomen, respectively. Values of 25-33 Gy cm^2 were obtained for retrograde cystourethrographies and ERCP, and values of 62-158 Gy cm^2 were obtained for nephrostomy and percutaneous transhepatic cholangiography. The correlation between total fluoroscopy time and the DAP values was poor. Mean effective dose estimates showed lower values for extravascular procedures (4.8-28.2 mSv), intermediate values for neuroradiological procedures (12.6-32.9 mSv) and higher values for vascular procedures involving the abdomen (36.5-86.8 mSv). The median values of DAP for all the procedures were 11.4 Gycm^2 and 6.6 minute, respectively. For the DDD, VDD, and VVI pacemakers implanted. (Radiol Med. 2004).

During long procedures the threshold of the deterministic effects might be reached. Since the severity of the lesion is dose dependent one should define a DAP level (for example 100Gy.cm2) after which a particular care on patient exposure is exercised. One could try for Example to change incidences to distribute the dose. A DAP threshold where the patient should be recalled to check for skin lesion should also be defined (for example 500 Gy.cm2). Most of this data came from Radiobiology for the Radiologist, by Eric Hall or BEIR V, National Academy of Science. Ranges have been given if known. All doses are TEDE (whole body total) unless otherwise noted. (http: //www.physics.isu.edu/radinf/risk.htm)

1.4 Radiation risk and over exposure

It isimportant to know the radiological doses involved in medical imaging, because the radiological dose is directly and linearly related to risk. There is always a risk of damage to cells or tissue from being exposed to any amount of ionizing radiation. Over time, exposure to radiation may cause cancer and other health problems. But in most cases, the risk of getting cancer from being exposed to small amounts of radiation is small. The chance of getting cancer varies from person to person. It depends on the source and amount of radiation exposure, the number of exposures over time, and your age at exposure. In general, the younger you are when

you are exposed to radiation, the greater the risk of cancer.The benefits of properly performed interventional fluoroscopy almost always outweigh the radiation risk experienced by an individual. However, unnecessary exposure to radiation can produce avoidable risk t Radiation causes ionizations in the molecules of living cells. These ionizations result in the removal of electrons from the atoms, forming ions or charged atoms. The ions formed then can go on to react with other atoms in the cell, causing damage. An example of this would be if a gamma ray passes through a cell, the water molecules near the DNA might be ionized and the ions might react with the DNA causing it to break. At low doses, such as what we receive every day from background radiation, the cells repair the damage rapidly. At higher doses (up to 100 rem), the cells might not be able to repair the damage, and the cells may either be changed permanently or die. Most cells that die are of little consequence, the body can just replace them. Cells changed permanently may go on to produce abnormal cells when they divide. In the right circumstance, these cells may become cancerous. This is the origin of our increased risk in cancer, as a result of radiation exposure. At even higher doses, the cells cannot be replaced fast enough and tissues fail to function. An example of this would be "radiation sickness." This is a condition that results after high doses to the whole body (>100 rem), where the intestinal lining is damaged to the point that it cannot perform its functions of intake of water and nutrients, and protecting the body against infection. This leads to nausea, diarrhea and general weakness. With higher whole body doses (>300 rem), the body's immune system is damaged and cannot fight off infection and disease. At whole body doses about400 rem, if no medical attention is given, about 50% of the people are expected to die within 60 days of the exposure, due mostly from infections. If someone receives a whole body dose more than 1,000 rem, they will suffer vascular damage of vital blood providing systems for nervous tissue, such as the brain. It is likely at doses this high, 100% of the people will die, from a combination of all the reasons associated with lower doses and the vascular damage. There a large difference between whole body dose, and doses to only part of the body. Most cases we will consider will be for doses to the whole body. Or both the patient and the operator. (http://www.cigna.com/individualandfamilies health)

1.4.1 Risk to patients

The short-term risk to patients is radiation-induced skin damage, which can result from acute radiation doses of >= 2Gy. The extent of the skin injury may not be known for weeks after the procedure. Repeated procedures increase the risk of skin injury, because previous radiation exposure sensitizes the skin.Long term effects include the potential risk of cancer. It is generally accepted that there is probably no low dose "threshold" for inducing cancers, i.e. no amount of radiation should be considered absolutely safe. Recent data from the atomic bomb survivors

(Pierce 2000) and medically irradiated populations (UNSCEAR 2000) demonstrate small, but significant increases in cancer risk even at the level of doses that are relevant to interventional fluoroscopy procedures. The increased risk of cancer depends upon the age and sex of the patient at exposure. Children are considerably more sensitive to radiation than adults, as consistently shown in epidemiologic studies of irradiated populations. (http://www.physics.isu.edu/radinf/risk.)

1.4.2 Patient and Staff Exposure

According to the 'as low as reasonably achievable' (ALARA) and optimization principles it is necessary to minimize patient dose in order to outweigh the radiation risk by the benefit of the interventional procedure. We must balance the risks with the benefit. It is something we do often. We want to go somewhere in a hurry, we accept the risks of driving for that benefit. We want to eat fat foods; we accept the risks of heart disease. Radiation is another risk which we must balance with the benefit. The benefit is that we can have a source of power, or we can do scientific research, or receive medical treatments. The risks are a small increase in cancer. Risk comparisons show that radiation is a small risk, when compared to risks we take every day nearly. It is not a mysterious source of disease, but a well-understood phenomenon, better understood than almost any other cancer causing agent to which we are exposed.

(http://www.sirweb.org/patients/radiationSafetyStatements.shtml)

1.5Problem of study

Radiation protection (RP) for patients and staff is one of the main issues in Interventional Radiology (IR). UNSCEAR, ICRP and IAEA have devoted significant time over the last years to improve radiation safety in IR. Several combined factors: prolonged localized fluoroscopy, multiple radiographic exposures, and repeated procedures can cause acute radiation injury to the skin. The values of dose-area product and effective dose for IR are typically larger than those used in common diagnostic x-ray examinations. Interventional radiology has developed into a

dynamic part of radiology over the past twenty years, combining diagnostic and therapeutic methods. On the other hand, it is associated with high radiation doses to patient and staff, due to extended fluoroscopyIn IR, the combination of prolonged localized fluoroscopy, multiple radiographic exposures, and repeated procedures can cause patient doses to reach levels producing acute coetaneous radiation injury. Procedures of particular concern in this respect include radio-frequency cardiac catheter ablation, PTCA, vascular embolization, stent and filter replacement, thrombolytic and fibrinolytic procedures, percutaneous transhepatic cholangiography , endoscopic retrograde cholangiopancreatography, transjugular intrahepatic ortosystemic shunt, percutaneous nephrostomy, and biliary drainage or urinary/biliary stone removal times and the large number of radiographs. Also, occupational exposures from interventional radiology procedures have a tendency to be greater than other radiological examinations.

The need for measuring and evaluating patient and staff doses is apparent Because no regular QC, no personal dosimetry, lack of awareness of staff, No reporting dose level for patients and few studies was performed in dose for intervention radiography.

1.6 Objectives

1.6.1Main objective

The main objective of this study to evaluate patient and staff doses in interventional radiology

1.6.2 Specific objectives

The specific objective to:

- Identify procedures associated with higher radiation doses in intervention radiology
- Determine patient radiation doses and staff for interventional radiology.
- Determine the effects of various parameters on patient and staff doses.

1.7 Thesis Outline

This thesis is concerned with the evaluation of patient and staff doses in interventional radiology. Accordingly, it is divided into the following chapters:

Chapter one is the introduction to this thesis. This chapter discusses the objectives and scope of work and introduces necessary background. It also provides an outline of the thesis.

Chapter two contains the literature and theoretical background material for the thesis. Specifically it discusses the dose for all absorbed dose measurements and calculations. This chapter also includes a summary of previous work performed in this field.

Chapter three describes the materials and a method used to measure dose for C-arm machines and explains in details the methods used for dose calculation.

Chapter four reveals and demonstrates the results of this study.

Chapter five presents the discussion, conclusion and recommendations of the thesis and gives suggestions for future work.

Chapter two: literature view

Chapter two: literature view

2.1 C-Arm X-ray machine

An X-ray image intensifier (XRII), sometimes called a C-Arm, refers to a special image intensifier device used in medical imaging involving x rays. It consists of an input window, input

phosphor, photocathode, vacuum and electron optics, output phosphor and output window. It allows for lower x-ray doses to be used on patients by magnifying the intensity produced in the output image, enabling the viewer to easily see the structure of the object being imaged. C-Arms were introduced by Philips in 1955. "C-Arm" is a name given to specialized X-ray imaging machines, due to their special arced semi-circular design. C-Arms use X-rays for imaging, but are designed to work with lower amounts of exposure. C-arms are one of the driving technological forces behind the advancement of minimally invasive surgeries. These mobile fluoroscopic imaging systems are precise and accurate devices that allow for less patient discomfort in a variety of surgical and nonsurgical procedures. The minimal invasiveness with the use of C-arms has helped lead to the increase of more cost-effective outpatient care. C-arms provide patients with minimally invasive, pain-reduced procedures.

Initially used in general surgery or orthopedic applications, C-arms are now described by both manufacturers and users as highly versatile. In fact, C-arm usage recently has expanded to include minimally invasive, spinal, general, and orthopedic surgeries; pain management; and cardiac, urology, vascular, and neurovascular applications. (www.ehow.com/facts_5598572_arm-xray-machine-used-for_.html)

2.1.1 Advantages of C-arm X-ray machine

C-Arm x-ray machines use intensifiers that magnify readings. This allows lower amounts of X-rays to be used, and results in less radiation exposure for patients and professionals. Advanced technologies for improved patient care Move it easily into place, set it up fast and get exceptional images. With easy steering, customized one-button presets and clear dynamic imaging, our mobile c-arm surgery systems are designed to address a wide variety of clinical requirements. You will find high penetration, high-quality 3D imaging, even at the steepest projections, simple to achieve. (www.ehow.com/facts_5598572_arm-xray-machine-used-for_.html)

2.1.1.2Applications

C-Arm machines are often smaller than traditional units, and can be used in more confined spaces. This size advantage also enables applications such as mobile screening rooms. An image intensifier or is used in two ways:

1. As a Fixed piece of equipment in a dedicated screening room
2. Mobile Equipment for use in theatre.

2.1.1.2.1 Fixed Image Intensifiers

These are used in most X-ray departments as 'screening rooms'. The types of investigations for which this machine can be used for is vast. Examples include:

Barium Studies (Swallows, Meals, Enemas) Endoscopy Studies (ERCP) Fertility Studies (HSG) Angiography Studies (Peripheral, Central and Cerebral). Therapeutic Studies (Line placements i.e. Permacath / Hickman, Transjugular Biopsies, TIPS Stent, Embolisations) Cardiac Studies (PTCA).

2.1.1.2.2 Mobile Image Intensifiers (MII)

Smaller in design than a fixed image intensifier, mobile screening units are becoming more and more powerful. This has enabled more advanced and technical procedures to be carried out in confined locations. MII's are routinely used in most hospitals for:

Orthopedic imaging in theatre (DHS, ORIF's and MUA's) Neurolgical Imaging in theatre Endovascular Imaging in theatre (EVAR) Therapeutic Procedures in theatre (pain clinic). www.ehow.com/facts_5598572_arm-xray-machine-used-for_.html

2.1.1.3 Capabilities

C-Arm imaging equipment is capable of being adjusted to different settings depending on the application. This means that X-ray exposure can be fine-tuned, and results in lower radiation

levels. Image intensifiers are usually set up for two purposes. For either plain fluoroscopy or digital subtraction angiography (DSA). All image intensifiers are set up with software capable of adjusting settings to suit different user requirements, depending on the procedure and body area being imaged. In simple fluoroscopy for example, imaging of the throat would not require the same amount of exposure as that of the abdomen. And on DSA capable models, preset programs are available which enables the user to decide a rate of how many images or frames per second are acquired. www.ehow.com/facts_5598572_arm-xray-machine-used-for_.html

2.1.1.4 Comfort

By being small and adjustable, C-Arm units offer increased patient comfort compared to traditional models. This minimal invasiveness also allows faster diagnosis and treatment for patients.

2.1.1.5 C-arms with Flat Detector

Gives you the clarity, space and convenience to carry out surgical procedures and the most challenging minimally invasive interventions with confidence

2.1.1.6C-arms with Image Intensifier

Our fully optimized digital imaging chain with 9” and 12” CCD technology delivers advanced noise reduction and true 1k x 1k imaging**.**

2.1.2 C-arm X-ray machine component

Components of chain are: X-Ray collimator, image intensifier, system and the fluoroscopic imaging generator, x-ray tube, filters, patient table, Grid, optical coupling, television image recording.

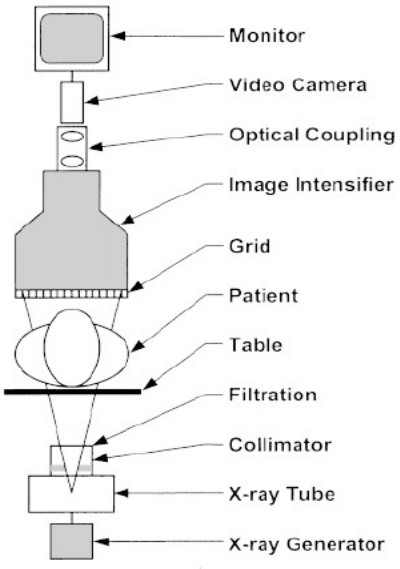


Fig 2.1: Components of the fluoroscopic imaging chain.

2.1.2.1 X-ray generator

Produces electrical energy and allows selection of kilovolt peak (kVp) and tube current (mA) that is delivered to x-ray tube.

2.1.2.2 X-ray tube

Converts electrical energy of x-ray generator to x-ray beam, Source of radiation; want to increase distance from x-ray tube.

2.1.2.3Collimator

Contains multiple sets of shutter blades that define the shape of the x-ray beam, there is a rectangular and a round set of blades. By further collimating the beam, or "coning down" to the area of interest, the exposed volume of tissue is reduced, which results in less scatter production and better image contrast. It also reduces the overall patient and surgeon radiation dose by minimizing scatter and direct exposure.

2.1.2.4 Patient table and pad

Must balance adequate strength to support the patient's body weight while minimizing x-ray attenuation; this can be accomplished with carbon fiber composite materials. Thin foam pads are better than thick gel pads.

2.1.2.5 Image intensifier

Converts x-rays and amplifies image brightness. Major components include an input layer to convert x-rays to electrons, electron lenses to focus the electrons, an anode to accelerate them, and an output layer to convert them into a visible image. There are different diameters (mini versus standard C-arm) that can accommodate body parts of various sizes.

2.1.2.6 Optimizing C-arm position

Most often, there will be a radiology technician operating the C-arm. However, it is important to understand how the C-arm moves so that you can direct the technician.

The C-arm unit can be maneuvered in various ways, depending on whether one moves the entire unit or just the C-arm. The position of the image intensifier is also important.

2.1.2.6.1 Move the entire unit

2.1.2.6.2 Move only the C-arm

Cant - This enables one to angle the base cephalad or caudad

C" over - This enables one to move the C-arm in the plane of the C-arm and is most commonly used for obtaining AP, lateral, and oblique views

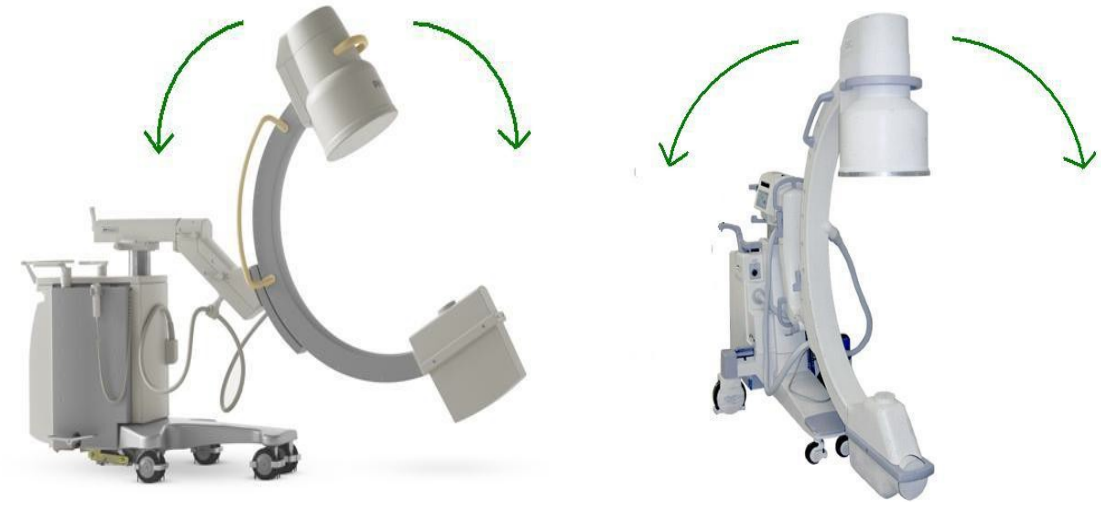


Fig: 2.2 C-arm mobile machine movements

2.1.2.7 Positioning the image intensifier (base)

Structures closer to the image intensifier will appear smaller compared to those further away. To increase the field of view, bring the base as close as possible to the structure of interest; this is particularly important for assessing alignment and also results in the least amount of radiation exposure for the patient and physician. In general, one should center the base of the C-arm over the area of interest.

2.1.2.8 Positioningthe C-arm

The final consideration is positioning the C-arm during pre-operative planning. It is difficult to work on the same side as the C-arm because of risk of contaminating the machine, in addition to the limited amount of space. It is easier to have the C-arm coming in from the opposite side of the area you will be operating on.

For example, when operating on a left ankle fracture, it is easier to position the C-arm on the right side of the room. However, when operating on the medial aspect of the left leg, it may be easier to position the C-arm on the left side so that there is more working area.

2.2 intervention radiology procedures

Fluoroscopy produces real-time images of internal structures of the body in a similar fashion to radiography, but employs a constant input of x-rays, at a lower dose rate. Contrast media, such as barium, iodine, and air are used to visualize internal organs as they work. Fluoroscopy is also used in image-guided procedures when constant feedback during a procedure is required. An image receptor is required to convert the radiation into an image after it has passed through the area of interest. Early on this was a fluorescing screen, which gave way to an Image Amplifier (IA) which was a large vacuum tube that had the receiving end coated with cesium iodide, and a mirror at the opposite end. Eventually the mirror was replaced with a TV camera.

Due to technology advances and high-quality imaging equipment becoming widely available, interventional radiologists are able to offer patients and referral physicians a host of treatment options. For details about these ailments and how IRs treat them, please select from the list of choices on the left side of your screen. A glossary of common interventional techniques is below.

2.2.1Angiography

An X-ray exam of the arteries and veins to diagnose blockages and other blood vessel problems; uses a catheter to enter the blood vessel and a contrast agent (X-ray dye) to make the artery or vein visible on the X-ray.

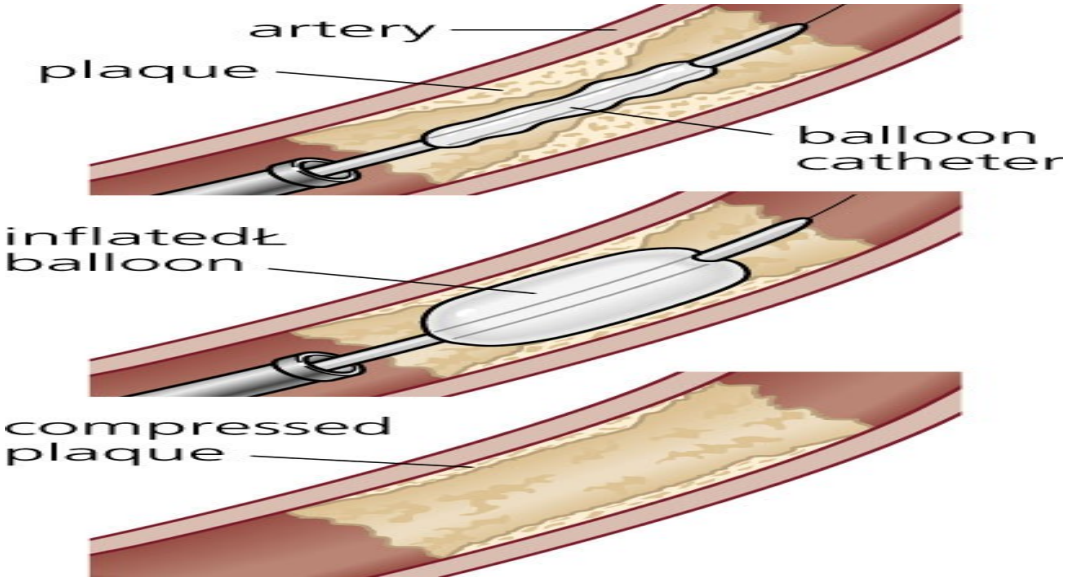


Fig 2.3 Interventional techniques are more complex and can require more extensive imaging for catheter or balloon support.

2.2.2 Arteriovenous Malformations (AVM)

Blood vessel abnormalities in the brain or elsewhere. If untreated, AVMs can rupture, causing life-threatening bleeding. Interventional radiologists can often treat these abnormalities without surgery by guiding thin catheters to the site and injecting a substance that blocks the supply of blood to the affected blood vessels.

2.2.3 Balloon Angioplasty

Opens blocked or narrowed blood vessels by inserting a very small balloon into the vessel and inflating it. Used by IRs to unblock clogged arteries in the legs or arms (called peripheral arterial disease or PAD), kidneys, brain or elsewhere in the body.

2.2.4 Biliary Drainage and Stenting

Uses a stent (small mesh tube) to open up blocked ducts and allow bile to drain from the liver.

2.2.5 Bleeding Internally

Interventional radiologists can pinpoint the area of internal bleeding with angiography and inject a clotting substance, such as a gel, foam or tiny coils, through a thin catheter to stop the bleeding.

2.2.6 Central Venous Access

Insertion of a tube beneath the skin and into the blood vessels so that patients can receive medication or nutrients directly into the blood stream or so blood can be drawn.

2.2.7Chemoembolization

Delivery of cancer-fighting agents directly to the site of a cancer tumor; currently being used mostly to treat cancers of the endocrine system and liver cancers.

2.2.8 Embolization

Delivery of clotting agents (coils, plastic particles, gel, foam, etc.) directly to an area that is bleeding or to block blood flow to a problem area, such as an aneurysm or a fibroid tumor in the uterus.

2.2.9 Gastrostomy Tube

Feeding tube inserted into the stomach for patients who are unable to take sufficient food by mouth.

2.2.10 Hemodialysis Access Maintenance

Use of angioplasty or thrombolysis to open blocked grafts for hemodialysis, which treats kidney failure.

2.2.11 High Blood Pressure

In some patients with high blood pressure, the condition is caused by a narrowing of the arteries in the kidneys. The problem, called renal hypertension, often can be treated with angioplasty.

2.2.12 Infection and Abscess Drainage

Patients with a variety of illnesses may develop an area of persistent infection (abscess) in the body. The infection can be drained by inserting a catheter through a small nick in the skin and to the site of the infection. Also used to treat complications of open surgery.

2.2.13 Needle Biopsy

Diagnostic test for breast, lung and other cancers; an alternative to surgical biopsy.

Dissolves blood clots by injecting clot-busting drugs at the site of the clot. Treats blood clots in the brain to reverse the effects of stroke; treats deep vein thrombosis in the leg to prevent permanent disability.

2.2.14 Radiofrequency Ablation

The use of radiofrequency (RF) energy is to "cook" and kill cancerous tumors.

2.2.15 Stent

A small flexible tube made of plastic or wire mesh, used to treat a variety of medical conditions (e.g., to hold open clogged blood vessels or other pathways that have been narrowed or blocked by tumors or obstructions).

2.2.16 Stent Graft

Reinforces a ruptured or ballooning section of an artery (an aneurysm) with a fabric-wrapped stent C a small, flexible mesh tube used to "patch" the blood vessel. Also known as an endograph.

2.2.17 Thrombolysis

Dissolves blood clots by injecting clot-busting drugs at the site of the clot. Treats blood clots in the brain to reverse the effects of stroke; treats deep vein thrombosis in the leg to prevent permanent disability.

2.2.18 TIPS (Transjugular Intrahepatic Portosystemic Shunt)

A life-saving procedure to improve blood flow and prevent hemorrhage in patients with severe liver dysfunction.

2.2.19 Urinary Tract Obstruction

The ureter carries urine from the kidneys to the bladder and sometimes becomes blocked by kidney stones or other obstructions. The interventional radiologist inserts a catheter through a small nick in the skin and into the blocked kidney to drain the urine.

2.2.20 Uterine Artery Embolization

An embolization procedure of uterine arteries to stop life-threatening postpartum bleeding, potentially preventing hysterectomy. The same procedure is used to treat fibroid tumors and is then called UFE (Uterine Fibroid Embolization).

2.2.21Uterine Fibroid Embolization

Cuts off the blood supply to the fibroid, causing them to shrink and die, and symptoms to subside (also known as uterine artery embolization).

2.2.22 Varicocele Embolization

A treatment is for "varicose veins" in the scrotum, which can cause male infertility and pain.

2.2.23Varicose Vein Treatment

The saphenous vein is sealed shut through the use of a laser or radio frequency non-surgically.

2.2.24 Vena Cava Filter

A tiny cage-like device is inserted in a blood vessel to break up clots and prevent them from reaching the heart or lungs Prevents pulmonary embolism.

2.2.25 Vertebroplasty

A pain treatment is for fractured vertebra in which medical-grade bone cement is injected into the vertebra.

2.3 Imaging techniques

In addition to planar X-ray imaging, there are a number of different imaging techniques which use X-rays. These include angiography, which uses injected iodinated contrast agents; fluoroscopy, which is a real-time imaging method often used in conjunction with barium contrast agents; and dual-energy imaging, which can produce separate images corresponding to bone and soft tissue.

2.3.1 X-Ray Angiography

Angiographic techniques produce images that show selectively the blood vessels in the body. This type of imaging is used to investigate diseases such as stenoses and clotting of arteries and veins and irregularities in systemic and pulmonary blood flow. In X-ray angiography, a bolus of iodine-based contrast agent is injected into the bloodstream before imaging. The X-ray image shows increased attenuation from the blood vessels compared to the tissue surrounding them. A related imaging technique is called digital subtraction angiography (DSA), in which one image is taken before the contrast agent is administered; a second after injection of the agent, and the difference between the two images is computed. DSA gives very high contrast between the vessels and tissue. Both DSA and conventional X-ray angiography can produce angiograms with extremely high spatial resolution, resolving vessels down to "" 100 μin diameter.

2.3.2 X-Ray Fluoroscopy

X-ray fluoroscopy is a continuous imaging technique using X-rays with very low energies, typically in the range 25-30 keY. This technique is used for placement of stents and catheters, patient positioning for interventional surgery, and many studiesof the GI tract. The X-ray source is identical to that described previously, except that a lower tube current (1-5 mA) and accelerating voltage (70-90 kV) are used, and so a small number of low-energy X-rays are produced. The inherently low SNR of the technique, due to a high level of quantum mottle, requires the use of a fluoroscopic image intensifier. A fluorescent screen is used to monitor continuously the area of interest within the body. The image intensifier is surrounded by mu-metal to shield the electrostatic lenses from interference from external magnetic fields. The input window of the intensifier is constructed either of aluminum or titanium, both of which have a very low attenuation coefficient at low X-ray energies. The input fluorescent screen contains a

thin, 0.2- to *OA-mm* thick, convex layer of sodium-doped cesium iodide (CsI:Na). This layer consists of columnar crystals, which are deposited directly onto the input window. Because both cesium and iodine have K-edges, 36 and 33 keV respectively, that are close to the energies of the X-rays being used, the probability of photoelectric interactions between the incoming X-rays and the screen is very high, with approximately 60% of the incoming X-rays being absorbed. The photoelectrons produced from these photoelectric interactions in the screen are converted into light photons within the phosphor layer. Roughly 2000 low-energy (2-eV, 400-nm) light photons are produced for every incoming X-ray photon. The light photons produced from the screen are absorbed by the photocathode and converted into photoelectrons. The photocathode, which contains antimony/cesium compounds, is in direct contact with the surface of the fluorescent screen. The maximum conversion efficiency of the photocathode occurs at 400 nm, matching the maximum output wavelength of the screen. The conversion efficiency at the photocathode is approximately 10%, that is, one photoelectron is produced for every 10 light photons striking the photocathode. These photoelectrons accelerate toward the positively charged anode, which has an applied potential difference of between 25 and35 kV. They are focused onto the output screen, which is made from a layer, a few micrometers thick, of silver-activated zinc cadmium sulfide. Electrostatic "lenses," consisting of negatively charged electrodes, are used for this focusing. The exact voltage applied to the electrodes can be varied to change the area of the output screen onto which the photoelectrons are focused, giving a variable image magnification factor. The output phosphor screen converts the photoelectrons into photons, with wavelengths in the visible range of 500-600 nm. These photons can be visualized directly or recorded via a video recorder. Electron absorption at the output screen is 90% efficient, with the final step of light generation typically producing 1000 light photons for every photoelectron absorbed. The inner surface of the output screen is coated with a very thin layer of aluminum, which allows the electrons to reach the output screen, but prevents light created in the screen from returning to the photocathode and producing secondary electrons. For every X-ray photon incident on the input screen, roughly 200,000 light photons are produced at the output screen. This represents an increase of a factor of 100 from the number of photons emitted from the input screen. The second factor in the high SNR gain of an image intensifier is that the diameter of the output screen is usually about 10 times smaller than that of the input screen, which ranges in size from small (23 em) for cardiac imaging to large (57 em) for abdominal studies. The increase in

brightness is proportional to the square of the ratio of the respective diameters, that is, approximately another factor of 100. In order for the image not to be distorted, each electron must travel the same distance from the photocathode to the output screen, and so a curved input screen must be used. A typical value of the spatial resolution at the center of the output screen is about 0.3 mm, with rv3-5% distortion due to differential electron paths at the edges of a 2.3-cm-diameter screen. Another important property of the intensifying screen is the signal retention, or "lag," from one image to the next. The value of the lag determines the maximum frame rate, that is, the highest number of images that can be acquired per second without signal from one image appearing in the next. X-ray fluoroscopy can be carried out in a number of modes. The simplest is continuous visualization or video recording of the signal, often referred to as "cine mode."Cine-mode fluoroscopy is often used in cardiac studies with two X-ray source/image intensifiers situated at an angle of 90° to one other. By alternating data acquisition from each detector and pulsing the X-ray source, frame rates up to 150 per second are possible Digital fluoroscopy can also be performed: in this case the video output of the camera is digitized and can be stored for subsequent data processing. Digital fluoroscopy is used for, among other applications, cardiac pacemaker implantation and orthopedic interventions.

2.3.3 Interventional orthopedic Radiology Imaging technique

Interventional orthopedic Radiology Imaging technique is the technique and process used to create images of the human body. In the clinical context, "invisible light" medical imaging is generally equated to radiology or "clinical imaging" and the medical practitioner responsible for interpreting (and sometimes acquiring) the images is a radiologist. "Visible light" medical imaging involves digital video or still pictures that can be seen without special equipment. Dermatology and wound care are two modalities that utilize visible light imagery. Diagnostic radiography designates the technical aspects of medical imaging and in particular the acquisition of medical images. The radiographer radiologictechnologist is usually responsible for acquiring medical images of diagnostic quality, although some radiological interventions are performed by radiologists. While radiology is an evaluation of anatomy, nuclear medicine provides functional assessment. As a field of scientific investigation, medical imaging constitutes a sub-discipline of biomedical engineering, medical physics or medicine depending

on the context: Research and development in the area of instrumentation, image acquisition , modeling and quantification are usually the preserve of biomedical engineering, medical physics, and computer science; Research into the application and interpretation of medical images is usually the preserve of radiology and the medical sub-discipline relevant to medical condition or area of medical science (neuroscience, cardiology, psychiatry, psychology, etc.) under investigation. Many of the techniques developed for medical imaging also have scientific and industrial applications

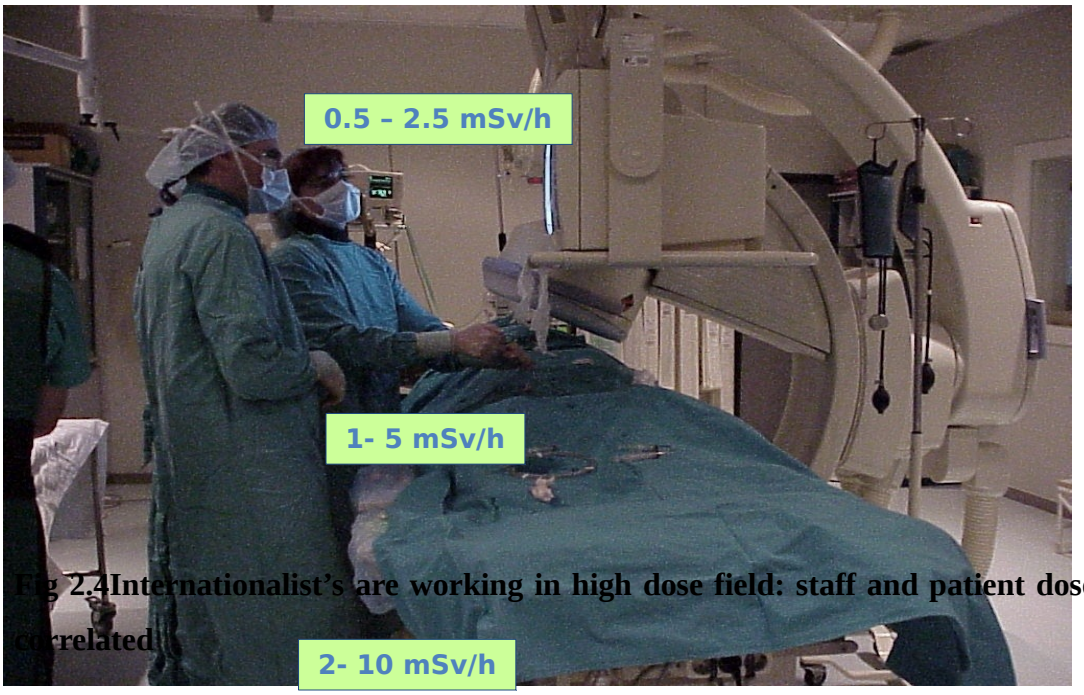


Fig 2.4Internationalist's are working in high dose field: staff and patient dose are correlated

2.4 Radiation dosemetry

Radiation dosemetry is the calculation of the absorbed dose in matter and tissue resulting from the exposure to indirectly and directly ionizing radiation. It is a scientific subspecialty in the fields of health physics and medical physics that is focused on the calculation of internal and external doses from ionizing radiation.

2.4.1 Radiation Units and Radiation Quantities

They include the many quantities that can be used to express the amount of radiation, the different units that are used, and the generally uneven distribution of the radiation within the patient's body. Also, some medical imaging procedures expose the staff to radiation. It is

necessary to determine their exposure so that the risk can be managed in the context of ALARA programs. Determining and expressing the radiation to the staff and other persons in an imaging facility is also somewhat complex because of the reasons mentioned above.

2.4.1.1 Radiation Units

Throughout the course of history there have been many different systems of units developed to express the values of the various physical quantities. In more recent times the metric system has gradually replaced some of the other more traditional or classic systems. This is also true for the units used for many of our radiation quantities.

2.4.1.1.1 Roentgen

The quantity of X-radiation which, when the secondary electrons are fully utilized and the wall effect of the chamber is avoided, produce in 1 cc of atmospheric air at 0°C and 76cm of mercury pressure such a degree of conductivity that 1 esu of charge is measured at saturation current. (http://en.wikipedia.org/wiki/Roentgen_(unit)

2.4.1.1.2The Rad

Is a deprecated unit of absorbed radiation dose, defined as 1 rad = 0.01 Gy = 0.01 J/kg. It was originally defined in (SI Unit) in 1953 as the dose causing 100 ergs of energy to be absorbed by one gram of matter. It has been replaced by the gray in most of the world. A related unit, the roentgen, was formerly used to quantify the number of rad deposited into a target when it was exposed to radiation. The F-factor can be used to convert between rad and roentgens.

2.4.1.1.3 The roentgen equivalent in man

The rem is defined since 1976 as equal to 0.01 sievert, which is the more commonly used SI unit outside of the United States. A number of earlier definitions going back to 1945 were derived from the roentgen unit, which was named after Wilhelm Röntgen, a German scientist who discovered X-rays. The acronym is now a misleading historical artifact, since 1 roentgen actually

deposits about 0.96 rem in soft biological tissue, when all weighting factors equal unity. Older units of rem following other definitions are up to 17% smaller than the modern rem**.**

2.4.1.1.4 Gray (Gy)

One gray is the absorption of one joule of energy, in the form of ionizing radiation, perkilogram of matter.

$$1Gy = 1\frac{J}{kg} = 1\frac{m^2}{s^2}$$

2.4.1.1.5 Sievert (Sv)

The gray and sievert units are both special names for the SI derived units of joules per kilogram (m^2/s^2 if expressed in base units), though they are not interchangeable.

1 Sv = 1 J/kg = 1 Gy

The gray is used with quantities of absorbed dose in any material, while the sievert is used with equivalent, effective, and committed dose in biological tissue. The latter quantities are weighted averages of absorbed dose designed to be more representative of the stochastic health effects of radiation, and use of the sievert implies that appropriate regulatory weighting factors have been applied to the original measurement. The dose equivalent in sieverts is equal to the absorbed dose in grays multiplied by the quality factor (1 Sv=100 rems).

2.4.1.1.6 Rem

Rem is the special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rems is equal to the absorbed dose in rads multiplied by the quality factor (1 rem=0.01 sievert). (http://en.wikipedia.org/wiki/Sievert)

2.4.1.1.7Curie

The original unit for measuring the amount of radioactivity was the (Ci)–first defined to correspond to one gram of radium-226 and more recently defined as: 1 curie = $3.7x10^{10}$ radioactive decays per second .[15]

2.4.1.1.8becquerel (Bq)

In the International System of Units (SI) the curie has been replaced by the Becquerel where:

1 becquerel = 1 radioactive decay per second = $2.703x10^{-11}$Ci.

2.4.1.2 Radiation Quantities

Radiation quantities used to describe a beam of x-radiation fall into two general categories as shown here. One category comprises the quantities that express the total amount of radiation, and the other comprises the quantities that express radiation concentration at a specific point. We need to develop this distinction before considering specific quantities.

2.4.1.2.1 Exposure

Exposure is a radiation quantity that expresses the concentration of radiation delivered to a specific point, such as the surface of the human body. The conventional unit is the roentgen (R) and the SI unit is the coulomb/kg of air (C/kg of air). Theunit, the roentgen, is officially defined in terms of the amount of ionization produced in a specific quantity of air. The ionization process produces an electrical charge that is expressed in the unit of coulombs. So, by measuring the amount of ionization (in coulombs) in a known quantity of air the exposure in roentgens can be determined. It is just about the right size for expressing exposure values encountered in medical imaging and it has a very convenient relationship to absorbed dose in rads for most soft tissues.The usual and appropriate use of the quantity, exposure, is to express the concentration of radiation delivered to a specific point, such as the Entrance Surface Exposure for a patient. Although knowing the surface entrance exposure to a patient does not give a complete description of the radiation delivered to all tissues, it does provide useful information for several purposes. Entrance Surface Exposure values can be used to

- Compare different imaging techniques with respect to radiation delivered to patients, especially for the same anatomical coverage.

- Calculate the absorbed dose to underlying tissues and organs.

Exposure is a dosimetric quantity for ionizing electromagnetic radiation, based on the ability of the radiation to produce ionization in air.This quantity is only defined for electromagnetic radiation producing interactions in air.Before interacting with the patient (Direct beam) or with the staff (scattered radiation), X- Rays interact with air The quantity “exposure” gives an indication of the capacity of X- Rays to produce a certain effect in air The effect in tissue will be, in general, proportional to this effect in air The exposure(x) is the absolute value of the total charge of the ions (Q) of one sign produced in air when all the electrons liberated by photons per unit mass (m) of air are completely stopped in air.

$$\mathbf{X = dQ / dm}$$

The SI unit of exposure is Coulomb per kilogram [C kg-1]the former special unit of exposure was Roentgen [R]

$$\mathbf{1\ R = 2.58 \times 10^{-4}\ C\ kg\text{-}1}$$

$$\mathbf{1\ C\ kg\text{-}1 = 3876\ R}$$

2.4.1.2.2 Absorbed dose, D

X-rays or gamma rays are indirectly ionizing radiation because energy is released into the Tissue through the electrons set in motion by the X-rays or gamma rays, which in turn will make a very large number of ionizations. The energy these electrons deposit per unitMass of tissue, T, or organ is called the absorbed dose and is denoted DT. This is the basic Physical quantity used to measure the biological effects expected. It has the dimension of One joule per kilogram (J kg-1) and is expressed in gray (Gy). This quantity is used to control the deterministic effects with a threshold of 0.5 Gy.

2.4.1.2.3Equivalent dose H

The equivalent dose H is the absorbed dose multiplied by a dimensionless radiation weighting factor, wR which expresses the biological effectiveness of a given type of radiation

- To avoid confusion with the absorbed dose, the SI unit of equivalent dose is called the sievert (Sv). The old unit was the “rem”
- **1 Sv = 100 rem**

To reflect the fact that all types of radiation for a given absorbed dose, do not produce the same affect in humans the concept of dose equivalent in a tissue, T, or organ, denoted HT Was introduced. It is the product of DT and a weighting factor, wR, which depends on the Type of radiation and expresses its effectiveness.

$$\mathbf{HT = \Sigma\ W_R\ .\ DT,R}$$

HT has the same dimension as DT (J kg-1), but is expressed in sievert (Sv).

W_R is Therefore equal to unity. Thus, an adsorbed dose of 1 mGy is equivalent to a dose equivalent

2.4.1.2.4Radiation weighting factor, W_R

For most of the radiation used in medicine (X Rays,γ and e-) W_R is = 1, so the absorbed dose and the equivalent dose are numerically equal**.** The exceptions are:

Alpha particles (W_R = 20)

Neutrons (W_R = 5 - 20).

Table 2.1: weighting factor for some organ or tissue W_T

Organ/Tissue	W_T	Organ/Tissue	W_T
Bone marrow	0.12	Lung	0.12
Bladder	0.05	Oesophagus	0.05
Bone surface	0.01	Skin	0.01
Breast	0.05	Stomach	0.12
Colon	0.12	Thyroid	0.05
Gonads	0.20	Remainder	0.05
Liver	0.05		

2.4.1.2.5 Effective dose, E

The effective dose (E) The aim of the E was to define a quantity that could be directly related to the probability of a detriment from low-dose exposure to ionizing radiation where only stochastic effects occur.

E is defined by the weighed sum of mean tissue and organ doses with radiation weighting Factors taking into account a) the different radio-biological effectiveness of various Radiations and b) the different sensitivity of tissue and organs with respect to stochastic

Effects. E is defined as:

$$\mathbf{E = \Sigma\ T\ W_T\ .\ HT = \Sigma\ T,RW_T\ .\ W_R\ .\ D_{T,R}}$$

Where

E: effective dose

W_T: weighting factor for organ or tissue T

HT: equivalent dose in organ or tissue T

To reflect the combined detriment from stochastic effects due to the equivalent doses in all the organs and tissues of the body, the equivalent dose in each organ and tissue is multiplied by a tissue weighting factor, wT, and the results are summed over the whole body to give the effective dose E.(Radiological protection of the worker in medicine and dentistry. Bethesda, USA, 1993.)

2.4.1.2.6 Entrance dose

For radiographic examinations, theabsorbed dose at the surface at the entrance of the beam in the patient and abbreviated as ESD. The ESD is expressed in mGy and is converted into effective dose, in mSv, by multiplying it by the wT factors.

The entrance surface dose is defined by the BSS as the absorbed dose in the center of the field at the surface of entry of radiation for a patient undergoing a radiodiagnostic examination, expressed in air and with backscatter.(Kim S, June 2009).

The entrance skin dose (ESD) is the absorbed dose in the skin at a given location on the patient. It includes the backscattered radiation from the patient. (Kim S, June 2009).

Absorbed dose is a property of the absorbing medium as well as the radiation field, and the exact composition of the medium should be clearly stated. Usually ESD refers to soft tissue (muscle) or water

Absorbed dose in muscle is related to absorbed dose in air by the ratio of the mass energy coefficients.(THE essential physics of medical imaging, second edition)

2.4.1.2.7Dose Area Product

Dose area product (DAP) is a quantity used in assessing the radiation risk from diagnostic x-ray examinations and interventional procedures. Itis defined as the absorbed dose multiplied by the area irradiated, expressed ($Gy*cm^2$) (sometimes $mGy*cm^2$ or $cGy*cm^2$).

Manufacturers of DAP meters usually calibrate them in terms of absorbed dose to air. DAP reflects not only the dose within the radiation field but also the area of tissue irradiated. Therefore, it may be a better indicator of the overall risk of inducing cancer than the dose within the field. It also has the advantages of being easily measured, with the permanent installation of a DAP meter on the x-ray set. Due to the divergence of a beam emitted from a 'point source', the area irradiated (A) increases with the square of distance from the source ($A \propto d^2$), while radiation intensity (I) decreases according to the inverse square of distance ($I \propto 1/d^2$). Consequently, the product of intensity and area, and therefore DAP, is independent of distance from the source. (Kim S, June 2009).

2.4.1.2.8 Air kerma

Air kerma is another radiation quantity that is sometimes used to express the radiation concentration delivered to a point, such as the entrance surface of a patient's body. The quantity, kerma, originated from the acronym, KERMA, for Kinetic Energy Released per unit Mass of Air. It is a measure of the amount of radiation energy, in the unit of joules (J), actually deposited in or absorbed in a unit mass (kg) of air. Therefore, the quantity, kerma, is expressed in the units of J/kg which is also the radiation unit, the gray (G). (The physical principle of medical imaging, ,Perry Sprawls, Ph.DP).

It is easy to measure with an ionization chamber. Since the ionization produced in air by radiation is proportional to the energy released in the air by the radiation, ionization chambers actually measure air kerma as well as exposure. An ionization chamber can be calibrated to read air kerma, or a conversion factor can be used to convert between air kerma and exposure values. It is expressed in a practical metric SI unit. Air kerma (energy released in a unit mass of air) is

expressed in the units of joule per kilogram, J/kg. This is also the unit gray, Gy, used for absorbed dose. Here is the easy part. If we know air kerma measured (or calculated) at a point where soft tissue is located, the absorbed dose in the tissue will be just about equal to the air kerma.(Radiological protection of the worker in medicine and dentistry. Bethesda, USA, 1993.

2.5Previous studies

There are many authors were made studies in this way for example J R WILLIAMS et, al, the interdependence of staff and patient dosesin intervential radiology, may 1997 they found that there were wide variations in dose and statistically significant differences in fluoroscopy time, number of images, DAP, and CD for different instances of the same procedure, depending on the nature of the lesion, its anatomic location, and the complexity of the procedure.

Most procedures studied can result in clinically significant radiation dose to the patient, even when performed by trained operators with use of dose-reducing technology and modern fluoroscopic equipment. Embolization procedures, TIPS creation, and renal/visceral artery stent placement are associated with a substantial likelihood of clinically significant patient dose. At minimum, patient dose data should be recorded in the medical record for these three types of procedures. These data should include indicators of the risk of deterministic effects as well as the risk of stochastic effects. Also the Department of Radiology in USA, et al, Reference Levels for Patient Radiation Doses in Interventional Radiology: Proposed Initial Values for U.S. Practice 2009 were found the different methods for normalizing patient radiation dose according to patient weight gave results that were not significantly different ($P > .05$). The 75^{th} percentile patient radiation doses normalized with weight banding were not significantly different from those that were uncorrected for body habitus. Proposed initial reference levels for various interventional procedures are provided for reference air kerma, kerma-area product, fluoroscopy time, and number of images. Sufficient data exist to permit an initial proposal of values for reference levels for interventional radiologic procedures in the United States. For ease of use, reference levels without correction for body habitus are recommended. A national registry of radiation-dose data for interventional radiologic procedures is a necessary next step to refine these reference levels. nch, National Cancer Institute, Bethesda, Md(D.K).

AnotherauthersIoannisPantos et-al Patient Radiation Doses in Interventional Cardiology Procedures 2011measured the patient radiation doses due to prolonged fluoroscopy time and

radiographic exposurein interventional cardiology procedures the procedures that are most frequently performed are coronary angiography, percutaneous coronary interventions, diagnostic electrophysiology studies and radiofrequency catheter ablation. Patient radiation dose in these procedures can be assessed either by measurements on a series of patients in real clinical practice or measurements using patient-equivalent phantoms. In this article they review the derived doses at non-pediatric patients from 72 relevant studies published during the last 22 years in international scientific literature. Published results indicate that patient radiation doses vary widely among the different interventional cardiology procedures but also among equivalent studies. Discrepancies of the derived results are patient-, procedure-, physician-, and fluoroscopic equipmentrelated. Nevertheless, interventional cardiology procedures can subject patients to considerable radiation doses. Efforts to minimize patient exposure should always be undertaken.

Also the NationalResearch Council's Biological Effects of Ionizing Radiation VII Report,Cancer risk from professional exposure in staffworking incardiac catheterization laboratory:Insights from, American Heart JournalVolume 157, Number 1, Lucia Venneri, MD, PhD hit this way they found that the cardiac catheterization laboratory staff represented 67% of the 6 workers with yearly exposure N6 mSv.Of the 26 workers with 2006 exposure N2 mSv, 15 of them had complete records of at least 10 (up to 25) consecutive years.For these 15 subjects having a more complete lifetime dosimetric history, the median individual effective dose was46 mSv (interquartile range = 24-64). The median risk of (fatal and nonfatal) cancer (Biological Effects of Ionizingradiation 2006) was 1 in 192 (interquartile range = 1 in 137-1 in 370). In our cotnrey there are many studies in this way.

Donadl.Miller et al, determines patient radiation doses for interventional radiology and neuroradiology procedures in June 2003 A prospective observational study was performed at seven academic medical centers. There were wide variations in dose and statistically significant differences in fluoroscopy time, number of images, DAP, and CD for different instances of the same procedure, depending on the nature of the lesion, its anatomic location, and the complexity of the procedure. For the 2,142 instances, observed CD and DAP correlate well overall (r = 0.83, P< .000001), but correlation in individual instances is poor. The same is true for the correlation between fluoroscopy time and CD (r = 0.79, P< .000001). The correlation between fluoroscopy time and DAP (r = 0.60, P< .000001). Also Chu, Robert Y. L.; et; al 2006 Monitoring of skin

entrance radiation exposure in lengthy interventional procedures. Fluoroscopy duration and dose-area product (DAP) are readily available real-time measurements twenty neurological interventional procedures performed through the aortic arch were monitored An observer recorded the fluoroscopy duration and DAP for each phase of the procedure For these twenty cases, the means and standard deviations were 17.2 ± 6.4 min for x ray on-time, 256 ± 65 Gy cm^{-2} for DAP, 94 ± 34 cGy for peak skin entrance dose in air kerma, and 19.2 ± 5.0 mSv for effective dose, respectively. The peak skin entrance dose was correlated to fluoroscopy duration, DAP, and effective dose with the r^2-values of 0.48, 0.46, and 0.09, respectively. The correlation with DAP or fluoroscopy duration was not sufficiently strong to infer skin entrance dose from either of these parameters. Therefore, skin entrance dose should be determined directly; B J McParland made study in this way and found that the patient radiation doses in interventional radiological procedures in *1998* A total of 288 non-coronary procedures (177 classified as diagnostic and 111 as therapeutic)the dose-area product values for each is 24.2, 27.9, 69.6 and 74.7 Gy cm2 were obtained for nephrostomy, biliary stent removal/insertion, cerebral angiography and percutaneous transhepatic cholangiography procedures. Effective doses were estimated from the total dose-area products. The respective median estimated effective dose values for the four procedures noted above were 3.9, 4.5, 7.0 and 12.0 mSv. Also D Bor, PhD et al in 2004, measurements of dose–area product (DAP) and entrance dose were carried out simultaneously in a sample of 162 adult patients who underwent different interventional examinationsDose measurements for seven different angiographic examinations. Our fluoroscopy times and DAP values are approximately half of McParland's data (5 min and 23.8 Gy cm^2*vs* 10.3 min and 49.3 Gy cm^2) for the carotid procedures. However our effective doses are exactly the same (4.9 mSv).

A. Suliemanet al, Evaluation of Effective Dose to Patients Undergoing Cardiac Catheterization 2013 Study to a total of 50 consecutive patients who underwent cardiac catheterization using Kerma-area product (KAP) were measured. The average KAP ± SD of therapeutic anddiagnostic cardiac catheterization procedure was 46.4 $Gy.cm^2$ and ± 21.1 $Gy.cm^2$and 22.4 ± 2 $Gy.cm^2$, respectively. The average fluoroscopic time ± SD of cardiac catheterization was 24.1 ± 16.8 minutes and 37.2 ± 20.0 minutes. The estimated patient dose rate was found to be 125 mGy/min which considered higher than the recommended DRL for the continuous high mode fluoroscopy

used in interventional radiology (100 mGy/min). The study concluded to the fact that the patients received relatively high dose than previously reported studies.

Osman.H, et, al Wrote About Evalution Of Patient Radiation Dose During Orthopedic Surgery In Nasr City Cairo,Egypt On 25-28 November 2012, They Found That the orthopedic surgeries delivered lower radiation dose to patient than cardiac catheterization or hysteron salpinggraphy (HSG) to 37 patient under C-arm fluoroscopic machines ,in three centers in Khartoum-Sudan also AbdelmoneimSulieman, et, al They Wrote About Evaluation Of Occupational And Patient radiation doses in orthopedic surgery in CUSCO,PERU on April 13 to 16,2014 the measurement were performed in medical crops Hospital, Sudan, they found mean patient doses were 0.46 mGy and 0.07 for Dynamic Hip screw (DHS) and Dynamic Cannula screw (DCS) procedures , respectively . the mean staff doses at the thyroid and chest were 4.69 mGy and 1.21 mGy per procedure . the mean radiation dose for staff was higher in DHS compared to DCS . this can be attributed to the long fluoroscopic exposure due to the complication of the procedures.

Another author [Osman.H, etal,] wrote about orthopedist's hands radiation doses during orthopedics in 2013 they found the radiation dose for hands of orthopedist was 0.27 mGy per procedures +_ 0.09 . Compared results with previous studies , the present results were lower than previous studies . This results to 56 procedures of four different orthopedic surgeries were performed in three different centers in Khartoum-state.

Ahmed NA, Ibraheem SB and Habbani FI wrote about Patient doses in interventional cardiology procedures in Sudan on 11 Jul 2012.they found that the Radiation doses delivered to 461 patients were measured during the period of 12 months in a hospital in Khartoum, Sudan. Kerma Area Product, Cumulative Kerma and fluoroscopy time were registered during four selected procedures, namely coronary angiography (CA), percutaneous transluminal coronary angioplasty (PTCA), percutaneous transvenous mitral commissurotomy (PTMC) and pacemaker. For CA, PTCA, PTMC and pacemaker the mean and median kerma area product values in gray centimeter square were found to be (20, 17.9), (56.5, 50.3), (21.6, 19.6) and (15.3, 9.6), respectively. The obtained results for mean and median cumulative kerma in milli gray were (143.7, 120.5), (418.4, 371.4), (119.8, 102) and (88.7, 59.8) as measured for CA, PTCA, PTMC and pacemaker, respectively. The mean and median total fluoroscopy time in minutes were (5.2,

3.39), (17.6, 14.8), (18, 15) and (10.2, 7.16) as registered for CA, PTCA, PTMA and pacemaker, respectively. Maximum skin dose was estimated for 13 patients during PTCA and CA procedures. Dose exceeded 2 Gy in PTCA for one patient. In comparison with the guidelines for coronary examinations suggested by Sentinel Consortium, a higher fluoroscopy time for PTCA procedure is reported in this study. It is realized that proper selection of irradiation area, technique modes, fluoroscopy time and conducting special training on radiation protection to the operators are the main factors for potential optimization. Universal et, al wrote about Radiation doses to patients from permanent cardiac pacemaker implantation procedures on 28 Sep 2005, they found that For 55 procedures concerning three different types of pacemakers (DDD, VDD, and VVI), the dose-area product (DAP) meter readings and fluoroscopy times were recorded. From these data, the dose to the operating cardiologist was estimated. The median values of DAP and fluoroscopy time for all the procedures monitored were 11.4 $Gycm^2$ and 6.6 minute, respectively. For the 22 DDD, 21 VDD, and 12 VVI pacemakers implanted, the respective DAP median values were 14.7, 9.9, and 7.3 $Gycm^2$ and the respective median fluoroscopy times were 8.4, 5, and 2.9 minutes. (www.ncbi.mlm.gov/PubMed).

Chapter three: materials and methods

Chapter three: Materials & Methods

3.1 Patient and staff samples

A total of 826 patients and 44 staff were examined in different Hospitals. The data were collected using a sheet for all patients and staff in order to maintain consistency of the information. The following parameters were recorded age, weight, height, body mass index (BMI) derived from weight (kg)/ (height (m)) and exposure parameters were recorded. (Appendix1). The dose was measured for coronoraycathetrization. The examinations were collected according to the availability.

3.2 X-ray Machines

In the present study, four different modalities X-ray machines, from different manufacture were used as described in Table 3.1

Table 3.1 Type and main characteristics of X- ray machine

Center	Manufacturer	Manufactu-ring Date	Type	Focal spot (mm)	Total Filtiration	Max KVp	Max mA	Max time (s)	Year install

KTH(B)	Shimadzu	Jan 2003	Fixed (SFR)	0.5	1.5l	150	500	2.2	2005&2009
RCH	Toshiba	Jan 2010	Fixed (SFR)	0.5	1.5	150	500	2.2	Jun 2010
E-lMkNimer)	Shimadzu	Jan 11/2012	Fixed (SFR)	0.5	1.5l	150	500	2.2	8/2013
El-kuwaiti	Allengers	3/2012	Mobile	1.5mm	2mm	120	5	300	9/2013

Fig 3.1 C- arm machine in medical hospital

3.3 Pocket dosimeter

Electronic Personal Dosimeter , GRAETZ GPD150G , **with dose and dose rate alarm functions ;** dosemetry for measuring gamma radiation and X-rays for the dose equivalent $H_p(10)$, detector: energy compensated GM tube, switchable acoustic single-pulse indication, menu-driven user navigation, storage of the dose and of the set parameters even during battery change , 4 preset dose alarm thresholds: 200 µSv, 500 µSv, 1000 µSv, 2000 µSv

Dose rate alarm threshold is 25 µSv/h

- optical and acoustical alarm
- high reliability by continuous self control
- small and handy housing, easy to decontaminate, protection class IP54
- operating life with one battery set at ambient background radiation approx. 1 month during 24h operation and 3 months during 8h operation
- acoustic battery alarm.(**GRAETZ Strahlungsmeßtechnik GmbH)**

Fig 3.2: digital pocket dosimeter GPD150 product by PTW which used in this study.

Table 3.2 Technical Data for GPd150 pocket dosimeter

Technical Data	
Dose indication range	**0.05 µSv – 10 Sv**
Dose measuring range	**10 µSv – 10 Sv**
Dose rate range for dose measurement	**0.1 µSv/h – 1.0 Sv/h**
Energy range	**55 keV – 3 MeV**
Dose alarm thresholds	**4 preset values in the range of10 µSv – 10 Sv**
Dose rate alarm threshold	**25 µSv/h**
Temperature range	**-20°C up to +60°C**

Power supply	**2 batteries 1.5 V (type AAA)**
Acoustic alarm	**approx. 80 dB(A) in 30 cm distance**
Dimensions	**(59 x 71 x 25/17) mm**
Weight (batteries included)	**approx. 110 g (with plastic clip)**

3.4 Dap meter

Dose quantities in fluoroscopy fall into two categories. One that relates to stochastic risks (mostly cancer) and another to tissue reactions (deterministic risks) like skin injury. For adult patients in interventional procedures, risk of skin injury is more likely whereas for children the stochastic risk is more important. Staff risks are also largely stochastic. However, skin reactions occur if the operator's hands are frequently in the primary beam. Eye lens opacities have been observed in Internationalists who do not use adequate eye protection.[REHANI et al., 2011, CIRAJ-BJELAC et al., 2010].

These are two measured dosimetric quantities that can be used to estimate the radiation risks. Gy·cm^2 is used for estimating stochastic risk to patients while mGy relates to tissue reaction. Gy·cm^2 is a unit historically known as dose-area product (DAP) and currently named kerma-area product (KAP). The official notation recommended in ICRU report 74 is P_{KA}. [ICRU, 2005] KAP represents the product of the dose (in mGy, cGy, or Gy) at the center of a certain plane of the X-ray beam (e.g. the surface of the patient) multiplied by the area of the X-ray field at that plane (in cm^2 or m^2). Generally KAP is expressed as Gy·cm^2, cGy·cm^2, mGy·cm^2, µGy·cm^2. The IEC has recently standardized this to Gy·cm^2 [IEC, 2010]. KAP provides a good index for estimating stochastic risk but is not directly useful for estimating tissue reactions. Skin injury is related to the peak skin dose (PSD). There is no currently available real-time method to measure or calculate PSD. The dose at a defined reference point can be measured (Gy, cGy, mGy) and used to estimate PSD. For an iso-centric interventional fluoroscope, the reference point is located 15 cm from the isocenter toward the X-ray tube [IEC,2010]. The reference point moves with the gantry in such systems. Appropriate estimates of skin dose must account for gantry motion, patient size, and patient location relative to the gantry.

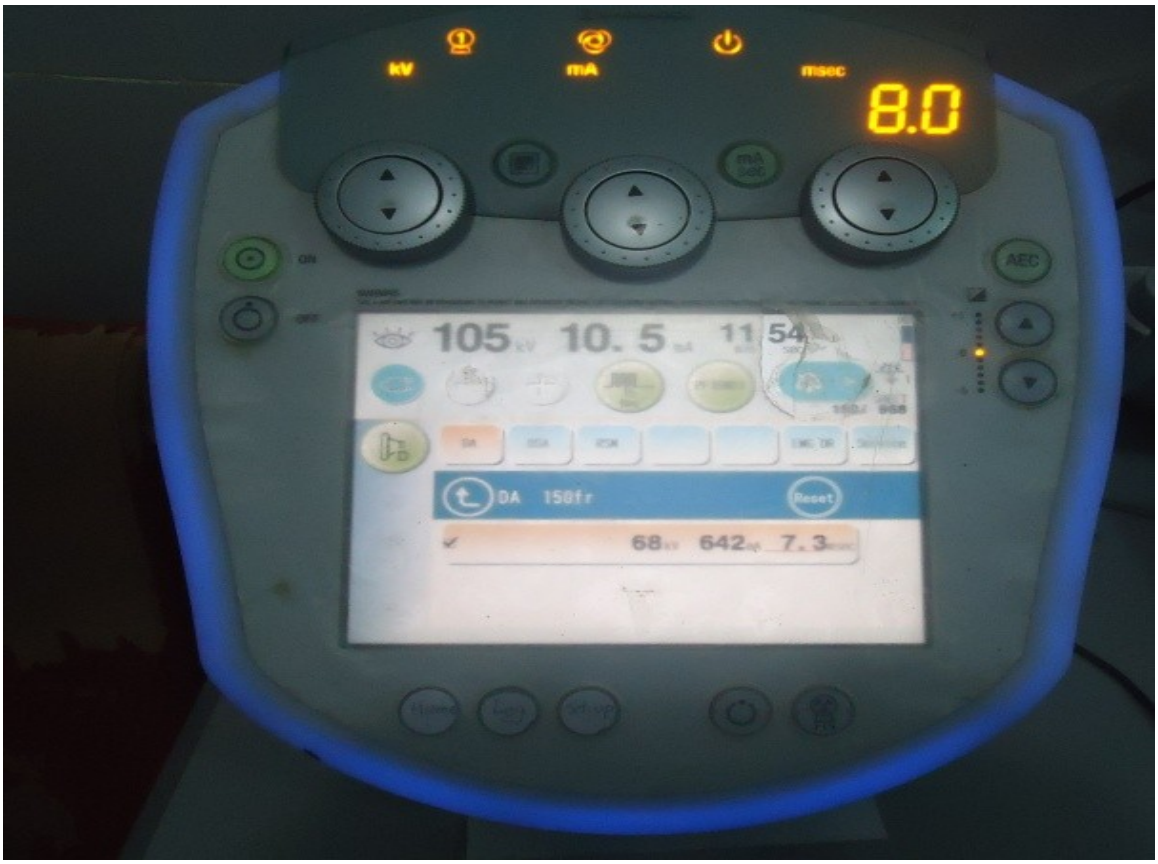


Fig 3.3 DAP meter in intervention radiology departments

KAP is frequently measured using a transparent ionization chamber mounted in the X-ray tube assembly between the collimators and the patient. In most fluoroscopic machines, the KAP chamber is hidden by the tube-housing cover. Some fluoroscopy machines calculate KAP using generator and collimator settings. KAP does not depend on the distance of the measuring plane from the X-ray source because dose decreases according to the inverse square law and the area of the field increases with the square of the distance. This keeps the KAP value constant at any distance. KAP represents the total energy incident on the patent. KAP is combined with a coefficient depending on the irradiated portion of the body and protocol (irradiated organs) to estimate effective dose (E). The coefficients range from 0.028 to 0.29 ($mSv/Gy{\cdot}cm^2$). They are derived from Monte-Carlo simulations using anthropomorphic digital phantoms (NCRP report 160 [NCRP, 2009]).

3.5 Rad check ™ **puls X-ray exposure meter**

Proven Rad-Check technology specifically designed to provide you with the ultimate in versatility and cost-effective operation. Fast and easy to use! Battery operation and built-in detector eliminate setup time. Measures dose up to 2 R; dose rate up to 20 R/min. Energy response is ± 5% from 30 to 150 kVp for the Rad check plus internal chamber. Optional remote chambers for mammographic and cine imaging systems. Extremely compact...6" x 6 1 /4" x 2 3 / 4" high; weighs only 18 oz. Rad check pluscan perform: Entrance skin exposure measurements (ESE), Fluoroscopy exposure measurements, Exposure checks, radiographic (mR/mAs). Beam quality; Half Value Layer (HVL), mAs reciprocity; mA Station Checks... Plus and many others, depending on the remote external chambers used.

3.5.1Automatic Reset after Exposure

There are no long cables (when the internal ionization chamber is used) or remote reset switches. Data accumulated during a prior measurement can be included in or eliminated from the next measurement. In addition, the unit can be reset manually. This precision electrometer features a tilt-stand for convenient positioning of the unit.

Battery operation and built-in detector virtually eliminate setup time. Just Rad check plus or external ion chamber on x-ray table; collimate, shoot and read the result.

3.5.2 Accuracy of Rad check

Precision ion chamber and digital display ensure accuracy plus easy readability. Accurate, lightweight, portable...this “industry standard” enables you to gain the critical edge in your QC program. 06-526 Rad check plus06-526-2200 Rad check plus, SI Units

3.5.3 Specification of Rad check

Ranges: 0.001 to 2 R, 0.01 to 20R/min Internal Chamber: 30 cc volume, energy response ±5% from 15-65 keV (30-150 kVp filtered). 20.5 cm2(5.1 cm diameter) effective measurement area. Center of Chamber 1.03 cm below top of chamberStandard Calibration: At 75 kVp with 4 mm Al filtration at 22° C and one atmosphereReproducibility: Within 2% short-term over 100 mR to 2 R range (1 mGy to 20 mGy)Electrometer Drift: 0.5 to 1 mR/minute typical; 6 mR/minute max (5 µGy to 10 µGy; 60 µGy/minute max)

3.6 Absorbed Dose calculations

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

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

Where:

(OP) is the output in mGy/ (mA s) of the X-ray tube at 80 kV at a focus distance of 1 m normalized to 10 mA s, (kV) the tube potential,(mA s) the product of the tube current (in mA) and the exposure time(in s), **(FSD)** the focus-to-skin distance (in cm).

(BSF) the backscatter factor, the normalization at 80 kV and 10 mAs was used as the potentials across the X-ray tube and the tube current are highly stabilized at this point. BSF is calculated automatically by the Dose Cal software after all input data are entered manually in the software. The tube output, the patient anthropometrical data and the radiographic parameters (kVp, mA s, FSD and filtration) are initially inserted in the software. The kinds of examination and projection are selected afterwards.

From this dose we can measure the dose per procedure, per week and per months and we can estimate the dose per year thus we can recommend if the dose per year more than threshold to reduce the number of procedures or the dose per procedure if passable.

3.7 Imaging technique

In addition to planar X-ray imaging, there are a number of different imaging techniques which use X-rays. These include angiography, which uses injected iodinated contrast agents; fluoroscopy, which is a real-time imaging method often used in conjunction with barium contrast

agents; and dual-energy imaging, which can produce separate images corresponding to bone and soft tissue.

Routine X rays examinations consist of two views, the frontal view (referred to as posterior anterior PA) and the lateral (side) view. For chest X rays it is preferred that the patient stand for this exam, particularly when studying collection of fluid in the lungs and during the actual time of exposure, the technologist usually asks the patient to hold his or her breath. It is very important in taking a chest x- ray to ensure there is no motion that could detract from the quality and sharpness of the film image.

3.8 Image protocol

In X- ray imaging the exposure parameters used are selected according to patient weight and organ size. The Standard (FFD) of 100 cm was used for all routine examination and the chest X-rays FFD of 180 cm are used for geometrical reason.

Chapter four: Results

Chapter four: Results

4.1: Results

Data were collected on four centers of interventional radiology procedures Khartoum Teaching Hospital (K.T.H), Royal Care Center (R.C.C), Kuwait Special Center (K.S.C) and ElmekNimer University Hospital (E.N.U.H) to evaluate the doses of 826 patients and 44 staff in 826 procedures.

There were widevariations in dose and statistically significant differences in fluoroscopy time, number of images, DAP, and CD fordifferent instances of the same procedure, depending on the nature of the lesion, its anatomic location, and thecomplexity of the procedure.

Table 4.1 patient, staff and type of procedures distribution in all hospitals

Hospital	Gender	KTH	R.C.H	K.S.H	E.N.U.H	Total	
Patient	Male	176	40	92	101	409	826
	Female	125	60	109	123	417	
Staff	Male	11	5	4	8	28	44
	Female	4	3	3	6	16	
Type of procedure		V.I + P	B.I	O.I	O.I + V.I	870	

KTH= Khartoum **T**eaching **H**ospital.

R.C.H= Royal **C**are **H**ospital.

K.S.H= Kuwait**S**pecial**H**ospital.

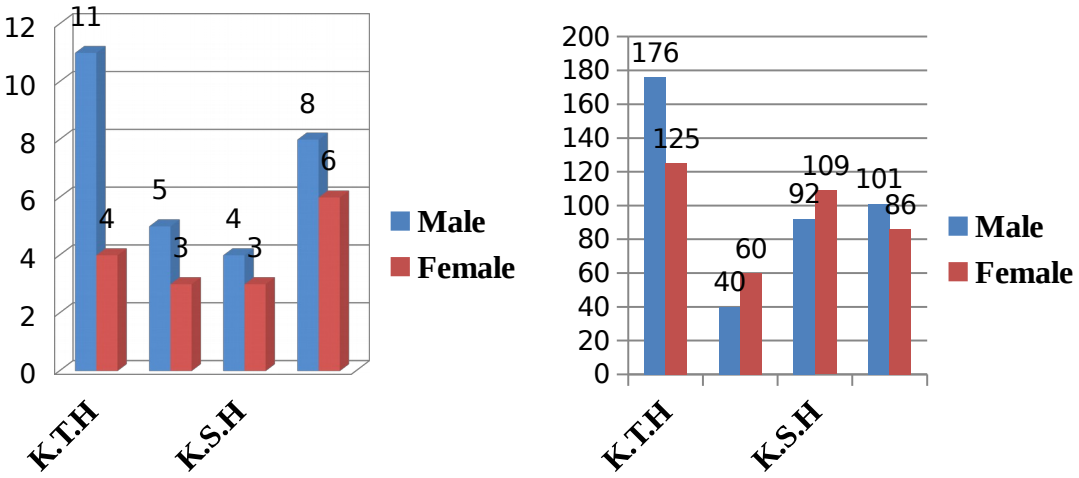
E.N.U.H= Elmek**N**imer**U**niversity**H**ospital.

IR = Intervention**R**adiography**; V.IR = V**ascular**I**ntervention**R**adiography**; P.IR = P**acemaker **I**ntervention**R**adiography**; O.IR=O**rthopedic**I**ntervention**R**adiography**.**

Table 4.2 patient demographic data in all hospitals

Hospital	Gender	Age	Weight	Height	B.MI
KTH	Male	77.37±13.21 (29-86)	66.76±24.04 (40-72)	1.64±0.07 (1.53-1.80)	24.59±6.48 (15.62-27.56)
	Female	59.70±29.01 (21-73)	67.86±14.82 (45-101)	1.61±0.03 (1.31-1.80)	26.03±5.44 (19.22-41.50)
R.C.H	Male	68.31±11.11 (53-89)	68.67±15.57 (38-115)	1.71±0.02 (1.54-180)	23.23±4.07 (16.02-36.30)
	Female	57.55±7.20 (15-69)	62.31±11.37 (40-72)	1.78±0.39 (1.53-1.82)	22.85±2.95 (14.25-26.26)
K.S.H	Male	62.12±10.00 (35-86)	78.04±7.00 (52-83)	1.23±0.15 (1.33-1.98)	21.16±0.17 (17.76-23.12)
	Female	64.85±20.16 (19-93)	70.76±14.04 (57-89)	1.59±0.11 (1.50-1.86)	24.12±3.66 (19.03-26.70)
E.N.U.H	Male	70.17±6.09 (65-80)	69.34±5.03 (40-91)	1.62±0.32 (1.49-1.63)	24.66±5.76 (20.17-27.34)
	Female	51.33±9.51 (27-96)	62.40±1.11 (51-73)	1.68±0.04 (1.23-1.90)	19.98±7.12 (15.66-25.22)
Total		63.93±13.29 (15-96)	68.17±11.62 (40-115)	1.61±0.14 (1.23-1.90)	23.24±4.45 (14.25-41.50)

BMI = **B**ody**M**ax **I**ndex



(a) **(b)**

Figure 4.1: distribution of(a) staff and (b) patient in all hospitals

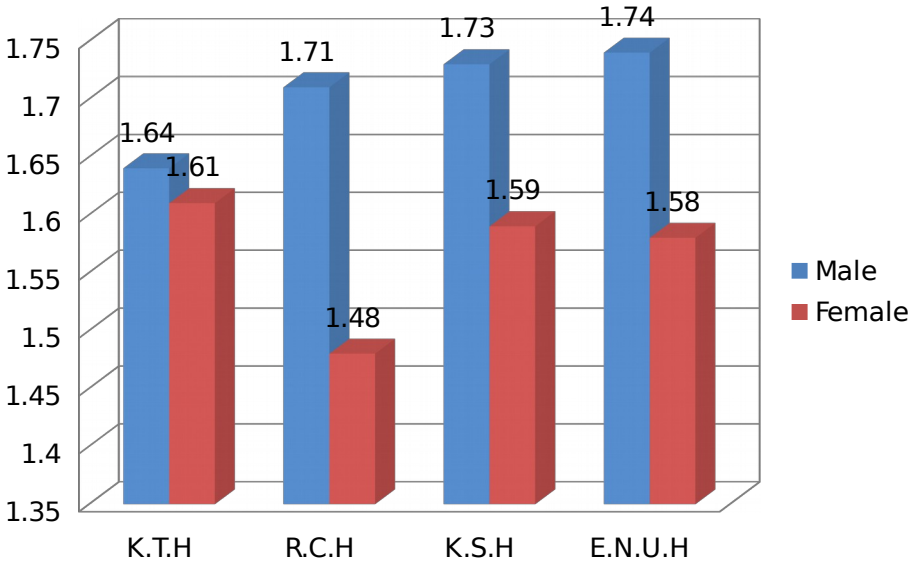
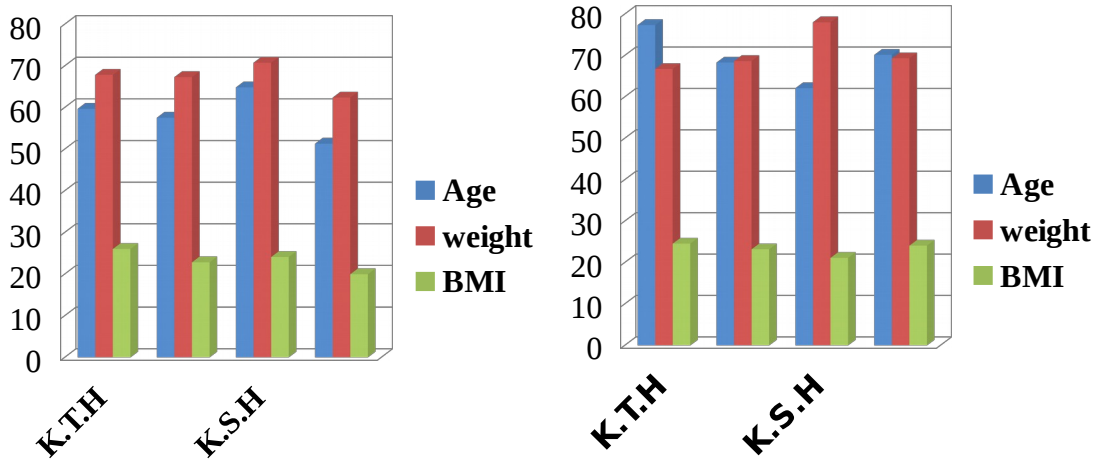


Figure4.2: height of patient in all hospitals



(a) **(b)**

Figure 4.3: patient demographic data for (a) female and (b) male in all hospitals

Table 4.3 staff demographic data in all hospitals

Title	Physician	Assistant	Nurse	Technician
Age	57.2±7.12 (37-64)	35.7±2.15 (27-40)	32.14±3.22 (30-50)	27.16±3.45 (20-32)
Weight	78.30±1.36 (75-93)	79.22±2.66 (64-87)	63.17±5.10 (47-77)	73.50±12.5 (66-78)
Height	1.79±0.08 (1.76-1.83)	1.61±0.53 (1.45-1.80)	1.72±0.56 (1.49-1.97)	1.65±0.03 (1.6-1.73)
BMI	24.97±9.14 (17.09-28.60)	22.48±2.42 (19.70-23.51)	21.30±1.08 (20.63-24.26)	22.49±1.05 (19.5-23.6)
No	8	8	20	8

Table 4.4 patient partial dose (mGy) data in vascular intervention radiology

Variable	N.O.E	$Cini_{second}$	Ft	ESD
Male	4.04±1.79 (1-6)	46.88±26.79 (0.00-71.57)	7.6±6.67 (1.5-41.6)	72.87±16.33 (39.75-116.84)
Female	4.19±1.72 (2-6)	67.86±14.82 (45-101)	5.90±3.70 (1.45-14.15)	75.52±7.91 (57.60-82.30)
Total	4.10±1.74 (1-6)	58.78±9.13 (34.67-71.57)	6.89±6.26 (1.45-41.60)	74.04±2.74 (39.75-116.84)

Table 4.5 Dosimetric Measurements per Type of vascular Intervention radiology

Examination	Total sample	Flouro time	Cini time(S)	DAP($Gy.Cm^2$)
CA	65	5.31	5.31	16.70
PCI	43	6.10	57.65	18.08

Table 4.6: Cini second, flouro time, entrance surface dose (mGy)andtotal dose (mGy) total dose (mGy) in pacemaker procedure.

Variable	$Cini_{second}$	F.t	ESD	T_{dose}
Male	15.75±8.68 (4-15.75)	11.68±9.70 (3.1-41.3)	43.47±4.31 (30.08-50.02)	808.87±0.88 (191.40-4337.3)
Female	21.56±11.81 (12-39)	11.38±8.72 (90-31.20)	47.03±4.95 (42.10-52.04)	666.5±135.1 (207.7-1205.6)
Total	17.98±9.96 (4-39)	11.56±9.20 (90-41.3)	46.30±4.50 (30.08-52.04)	785.05±148.77 (191.4-4337.3)

Table 4.7: Number of patient, total dose (mGy), entrance surface dose (mGy), fluoro time (S), cini second (S) and duration of procedures (min)fortype of Pacemaker.

Variable	No	T_{Dose}	ESD	Ft	$Cini_{second}$	$D_{of\ procedures}$

Pa_0	57	291.62±224.64 (30.50-804.50)	18.54±2.08 (9.69-20.54)	07.30±06.15 (0.90-26.70)	04.79±09.64 (0.00-28.00)	36.65±16.48 (10.0-70.0)
Pa_1	43	498.14±333.41 (66.70-1388.2)	40.31±1.36 (27.53-53.88)	12.24±6.45 (3.50-26.1)	09.87±12.78 (0.00-39.00)	40.92±11.66 (25.0-66.0)
Pa_2	13	937.42±180.86 (808.0-1205.2)	42.24±3.36 (26.15-59.19)	27.50±10.91 (18.60-41.3)	6.00±6.92 (0.00-12.00)	88.00±23.15 (70.0-120.0)

Table 4.8: type of procedures, number of cases and their parameters in O.IR

Procedure	No	Kv	mAs	Fluoro time (s)	No. of exp	Total time (min)
DHS	28	75.46±16.23 (64-103)	18.82±6.96 (10-45)	2.51±0.08 (2.40-2.70)	65.11±35.06 (19-125)	116.32±33.26 (37-192)
DCS	17	67.06±10.76 (60-84)	15.24±5.09 (3-45)	1.56±0.13 (1.3-1.8)	66.71±35.68 (13-127)	145.29±54.98 (50-232)
LPDF	9	66.89±8.85 (63-90)	12.07±2.36 (2-24)	1.79±0.30 (1-2)	10.44±1.51 (8-13)	130.78±49.64 (33-178)
Total	54	71.39± 14.11 (60-103)	14.71±5.22 (2-45)	2.10± 0.50 (1.0-2.70)	56.50± 37.10 (8.0-127)	127.85± 44.10 (33.0- 232.0)

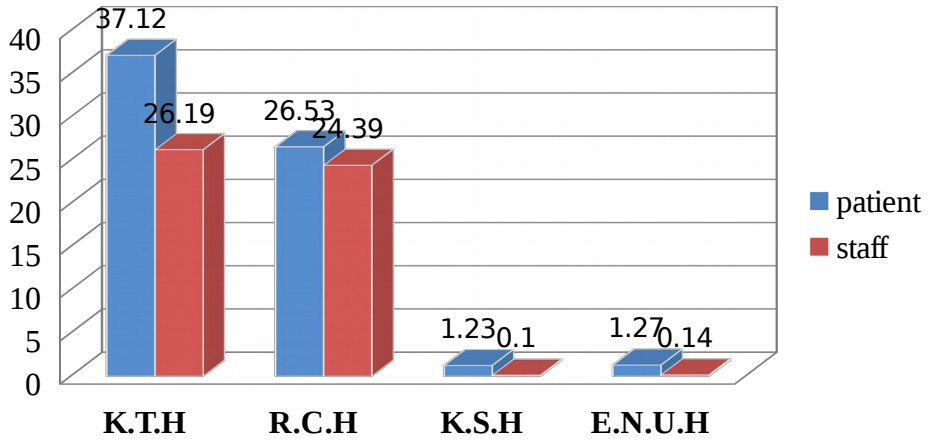


Figure 4.4: patient dose (mGy) and staff dose (µSv) in all hospitals

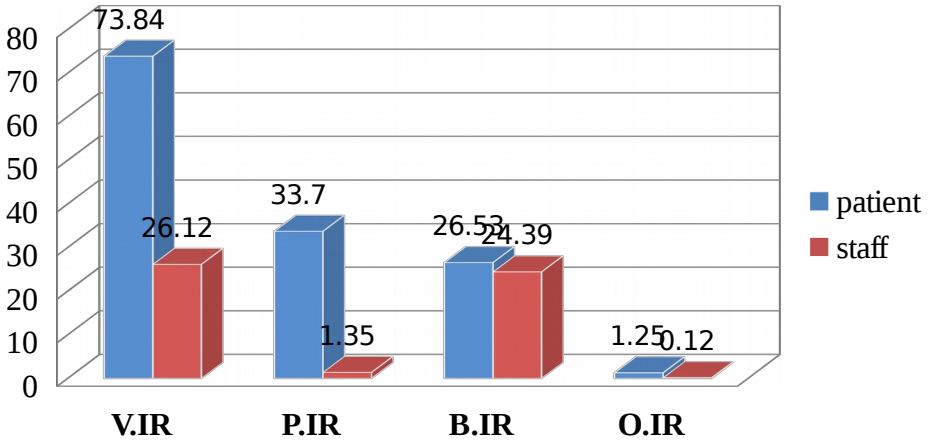


Figure 4.5: patient dose (mGy) and staff dose (µSv) in all procedures

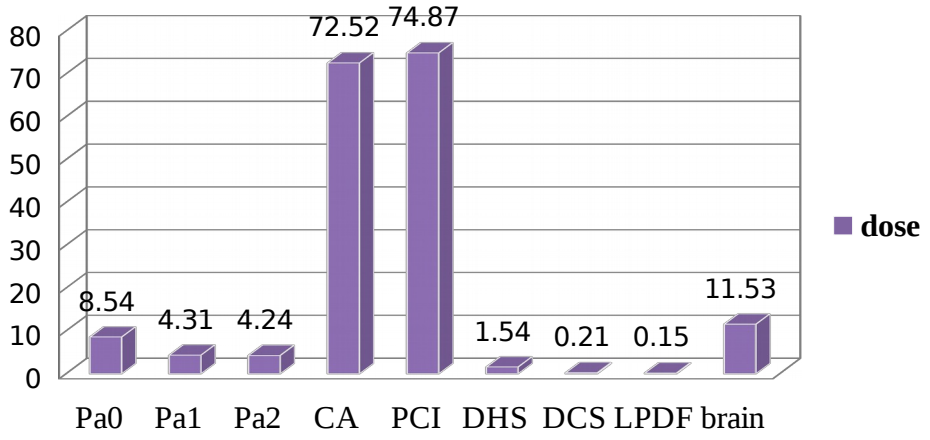


Figure 4.6: patient dose (mGy) in all type of procedures

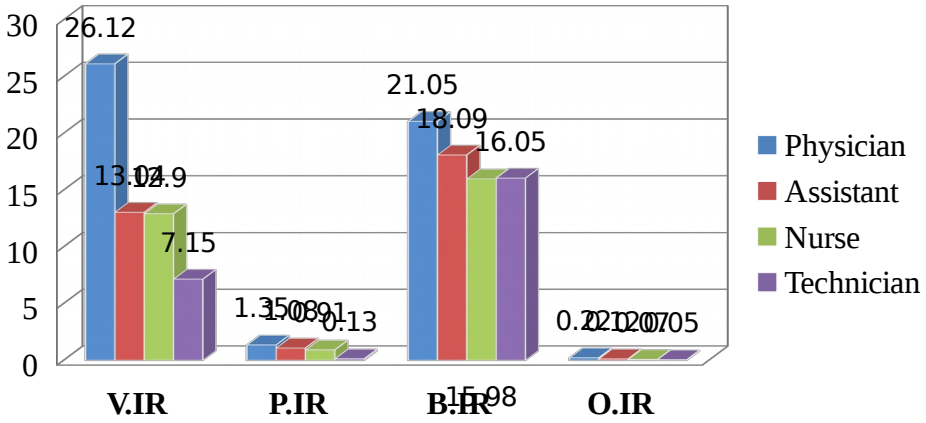


Figure 4.7: staff dose (µSv) in all procedures

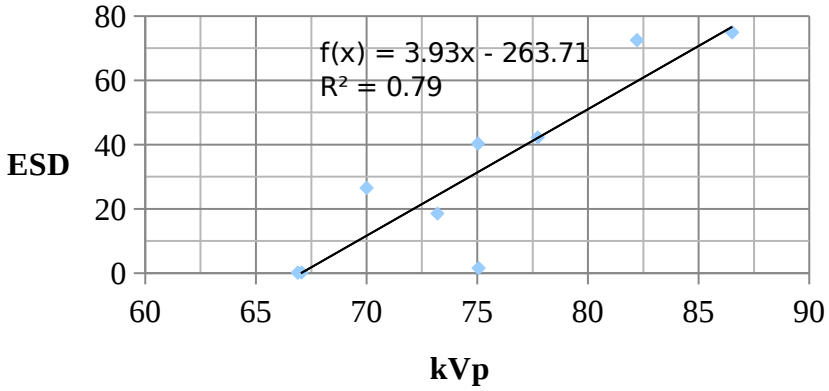


Figure 4.8: correlation between kVpand ESD (mSv) in all procedures

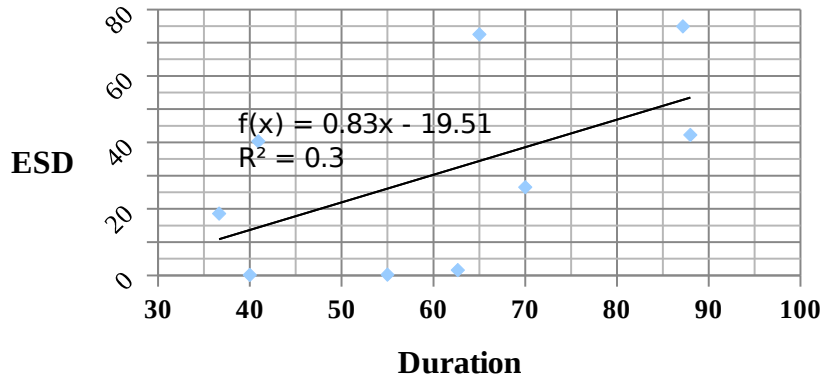


Figure 4.9: correlation between duration (Min) and ESD in all procedures

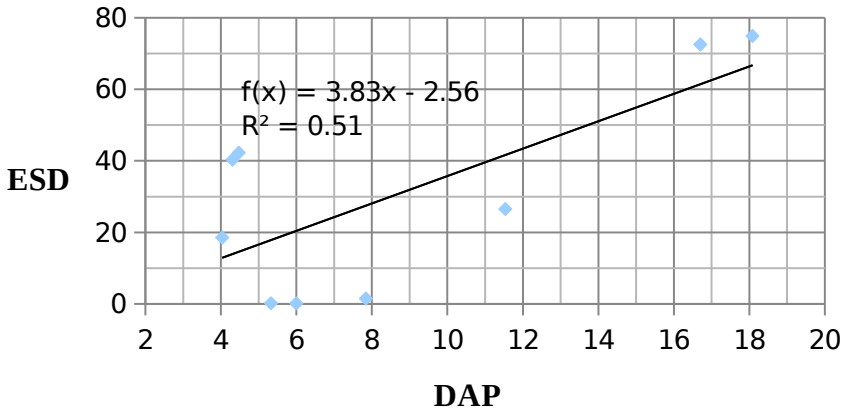


Figure 4.10: correlation between DAP (mGy.cm^2) and ESD in all procedures

Chapter five: Discussion,

Chapter Five: Discussion

5.1 Discussion

Most procedures studied can result in clinically significant radiation dose to the patient, even when performed by trained operators with use of dose-reducing technology and modern fluoroscopic equipment. Embolization procedures, TIPS creation, and renal/visceral artery stent placement are associated with a substantial likelihood of clinically significant patient dose. At minimum, patient dose data should be recorded in the medical record for these three types of procedures. These data should include indicators of the risk of deterministic effects as well as the risk of stochastic effects. lower doses because of biologic variation (Wagner et al.1999).

This study intends to evaluate the patients and staff radiation doses in intervention radiology for four procedures vascular intervention, pacemaker intervention, brain intervention and orthopedic intervention in four hospitals in Sudan Khartoum Teaching Hospital, Royal Care Hospital and ElmekNimer University hospital. A total of 826 adults patients and 44 staff were exposed in the

four hospitals equipped with C-Arm imaging modalities, 301 patients and 15 staff are exposure in Khartoum Teaching Hospital, 100 patients and 8 staff are exposure in Royal Care Hospital, 201 patients and 7 staff are exposure in Kuwait special Hospital and 224 patients and 14 staff are exposure in ElmekNimer University Hospital. Show in Tables (4.1-4.2).

The mean kv for vascular, pacemaker, brain and orthopedic intervention were 77.16, 76.41, 70.0 and 63.62 respectively. Whilethe mean mAs for the four procedures were 1344.32, 291.25, 530.75 and 600 respectively. Also the mean ESD for the four procedures were 73.69, 33.73, 26.53 and 1.22 respectively while the mean DAPfor the four procedures were 17.39, 4.31, 11.63 and 0.63 Gy. cm^2 respectively.

The mean doses of staff thatexposed in vascular intervention procedures were 26.12, 13.04, 12.9 and 7.15 µsVr for physician, assistant, nurse and technician respectively. The mean doses of staff that exposed in brain intervention procedures were 21.05, 18.09, 15.98, and 16.05 µsVr for physician, assistant, nurse and technician respectively.The mean doses of staff that exposed in pacemaker intervention radiology procedures were 1.35, 1.08, 0.91 and 0.13 µsVr for physician, assistant, nurse and technician respectively.The mean doses of staff that exposed in Orthopedic intervention radiology procedures were 7.15, 0.13, 0.05 and 0.05 µsVr for physician, assistant, nurse and technician respectively.

ESD, DAP were the highest in vascular intervention radiology procedure this because of using high Kv, high mAs and long duration as measured byJ R WILLIAMS et, al, and the Department of Radiology in USA, et al,.

Also in the staff the physician is the highest radiation dose one as measured bythe NationalResearch Council's Biological Effects of Ionizing Radiation VII Report,

Vascular intervention radiology which is highest procedure agreeswithIoannisPantos et-al and Donadl.Miller et alwhile in orthopedicintervention radiology agrees withOsman.H, et, al AbdelmoneimSulieman, et, al.

In this study correlation; between entrance skin dose ESD (mGy) compared totube potential kVp (kV), duration of the procedure (minute) and dose area product DAP (mGy.Cm^2); $R^2$are 0.794, 0.302 and 0.514 respectively which are good in kVp, duration of the procedure and DAP. Also the correlation between ESD and kVpincreased by 3.933 unit per 1 kVp unit while ESD increased by 3.83 unit per 1DAP unit.

5.2 Conclusions

Interventional radiology (IR) is a subspecialty of radiology usually minimally invasive procedures are performed using image guidance. The interventional procedures may be diagnostic or therapeutic. Staff dose arising from the use of x-rays are principally due to scattered radiation. Doses to patients in interventional cardiology or radiology are generally higher than other fluoroscopically guided procedures. Interventional radiology 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 the patient and exposed to none uniform radiation field due to patient scattered radiation consequently worker may receive over a period relatively doses. Interventional procedure requires long fluoroscopic time and considerable number of frames-images that causes significant dose values to patient and staff so it is important to follow attentively all radiation protection guidelines. All international organizations (ICRP, IAEA and WHO) supporting the international action plan and producing guidelines.

Factors affecting dose to patient and staff are fluoroscopy time, number of frames, field size, technical characteristics of radiation equipment, patient size and examination type and operation mode

Patients and staff radiation doses vary widely among the different interventional radiology procedures but also among published studies. Discrepancies of the derived results are patient, procedure, physician, and fluoroscopic equipment related. Nevertheless, IR procedures can subject patients to considerable radiation doses and efforts to minimize patient exposure should always be undertaken.

A prospective observational study was performed at four hospitals in two states Khartoum State (Khartoum Teaching Hospital, Royal Care Hospital and Kuwait Special Hospital) and River Nile State (ElmekNimer University Hospital). Each site contributed demographic and radiation dose data for subjects undergoing specific procedures in fluoroscopic suites equipped with built-in cumulative dose (CD) and dose–area–product (DAP). The accuracy of the dosimetry was confirmed by comprehensive measurements and by frequent consistency checks performed over the course of the study.

This study intends to evaluate patients and staff radiation doses in intervention radiology.

Patient doses were measuring during this study used on four hospitals to four types of interventional radiology procedures interventional cardiology procedures, pacemaker interventional procedures, brain intervention radiation procedures and orthopedic interventional procedures. I used (DAP) meter DIMENTOR M4 (PTW, Germany company) included to the C-arm machine.

I measured demographic data (age, weight, height, sex, clinical indication, and type of procedures). I used pocket dosimeter (GP 150) to measuring staff doses.

Four different X-ray C-arm machines were used throughout this study; four of them equipped with high frequency (HF) and the (AKP) not available, continues and pulse beam during different procedures.

In this study vascular interventional radiation doses values were higher than the other three types of procedures while orthopedic procedures is lowest onefigure (4.4, 4.5 4.6 and 4.7). Also the physician recorded highest doses while technician is the lowest one figure (4.4, 4.5 and 4.7)

5.3 Recommendations

- Advices the staff to use minimum Kv, minimum mAs, and minimum duration of the exposures as low as possible.
- More cases, more patients and more types of procedures can be used to reach more accuracy.
- More procedures must be used.
- More regulatory quality control test can be done for equipment and machines.
- More regulatory training can be done to staff in order to reduction duration of exposures thus reduce patients and staff doses.
- Usage of personnel dosemeter special pocket dosemeter if possible can distribute of control doses.
- We can minimize the use of fluoroscopy and using low fluoroscopy modes when possible.
- An experience one in any field can be found in the interventional radiology to minimize the radiation exposure duration.
- More studies in intervention radiology can be done to reach to best result and best expected.

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