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Original Research Article

Measurement of Patient Dose in Vascular Interventional Radiography

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Abstract: Cardiac catheterizations have contributed greatly to the treatment of heart diseases. However the radiation exposure to the patient is significantly higher compared with other radiological examinations. The objectives of this study are to evaluate the level of radiation dose received by the patients in order to introduce local diagnostic reference levels. A total of 108 consecutive patients who underwent cardiac catheterization using Dose-area product (DAP) were measured. The mean of DAP ± SD of therapeutic and diagnostic cardiac catheterization procedure was (80.84 ± 25.09) mGy.cm2 and (67.04 ± 26.65) mGy.cm2 respectively and for; male, female and total was (74.87± 41.33, 72.52± 27.91 and 73.84± 35.75) mGy.cm2 respectively. The mean of fluoroscopic time ± SD of therapeutic and diagnostic cardiac catheterization procedure was (6.10 ± 4.51 and 5.31 ± 2.96) minutes respectively and for male, female and total was (7.6±6.67, 5.90±3.70 and 6.89±6.26) minutes respectively. The mean of entrance surface dose ± SD of Therapeutic and diagnostic cardiac catheterization procedure was (80.8384± 25.08, 67.0351± 26.649) mGy respectively, and for male, female and total was, (74.87 ± 41.33, 72.52 ± 27.91 and 73.84 ± 35.74) mGy respectively. The study concluded to the fact that the patients received relatively high dose but the dose is necessary to enable the diagnosis or treatment and there are still minor differences with global standards.
Keywords: Interventional radiography, image intensify screen, dose area production, patient dose, optimization

INTRODUCTION

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 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 [1].

Coronary catheterization is a minimally invasive procedure to access the coronary circulation and blood filled chambers of the heart using a catheter. It is performed for both diagnostic and interventional (treatment) purposes. Coronary catheterization is one of the several cardiology diagnostic tests. Specifically, coronary catheterization is a visually interpreted test performed to recognize occlusion, stenosis, restenosis, thrombosis or aneurysmal enlargement of the coronary artery lumens; heart chamber size; heart muscle contraction performance; and some aspects of heart valve function. Important internal heart and lung blood pressures, not measurable from outside the body, can be accurately measured during the test. The relevant problems that the test deals with most commonly occur as a result of advanced atherosclerosis – atheroma activity within the wall of the coronary arteries. Less frequently, valvular, heart muscle, or arrhythmia issues are the primary focus of the test. Coronary artery luminal narrowing reduces the flow reserve for oxygenated blood to the heart, typically producing intermittent angina. Very advanced luminal occlusion usually produces a heart attack. However, it has been increasingly recognized, since the late 1980s, that coronary catheterization does not allow the recognition of the presence or absence of coronary atherosclerosis itself, only significant luminal changes which have occurred as a result of end stage complications of the atherosclerotic process.[2]

STAFF AND PATIENT EXPOSURE

Ionising radiation is a workplace hazard that cannot be detected by the human senses. The cardiovascular laboratory or cath lab is one such place where ionising radiation is much in use. The cath lab 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 cath lab is generally considered an area where exposure to radiation is particularly high. Factors such as the configuration of the 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 cath lab who wear single badges at the collar outside their lead aprons are generally amongst the highest in 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 [5]

Radiation in the cath lab 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 realised 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 cath lab 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) [6].

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 [7]. 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 up to 106 Gy.cm2 and 44 up to 143 Gy.cm2 respectively [5].

MATERIALS & METHODS

X-ray Machines

In the present study, three different modalities X-ray machines, from different manufacture were used as described in Table 1

Patient samples

A total of 48 patients were examined in Khartoum Teaching Hospital (KTH). The data were collected using a sheet for all patients in order to maintain consistency of the information. The following parameters were recorded age, weight, height, body mass index (BMI) derived from weight (kg)/ (height (m)) and exposure parameters were recorded. (Appendix1). The dose was measured for coronary catheterization. The examinations were collected according to the availability.

Imaging technique

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.

Table 1 Type and main characteristics of X-ray machine

Center	Manufacturer	Manufac tu-ring Date	Type	Focal spot (mm)	Total Filtration	Max KVp	Max mA	Max time (s)	Year install
KTH	Shimadzu	Jan 2003	Fixed (SFR)	0.5	1.5l	150	500	2.2	2005&2009

KTH= Khartoum Teaching Hospital

Patient preparation

- Patients may be required to be admitted to the hospital the night before the procedure. For some patients, overnight stay is not required.
- Nil per oral [NPO] or nothing to eat or drink by mouth 6-8 hours before the test.
- The cardiologist will explain the procedure and risks associated with it.
- Consent form should be signed before the procedure.
- Any questions or doubts should be asked and clarified with the doctor before surgery.
- The doctor should be informed of allergies to medications, iodine or food. It should also be documented legibly in the patient's chart.
- Previous allergic reactions to contrast dyes must be mentioned.
- Catheterization procedure requires X-ray fluoroscopy. Women patients in childbearing age can undergo pregnancy test to rule out pregnancy.
- Medications that are taken on the day of cardiac catheterization should be discussed with the doctor. Some medicines taken for blood thinning (e.g., Aspirin), erectile dysfunction (Sildenafil or Tadalafil) or diabetic medication (Metformin) needs to be stopped on the day or few days before the procedure.
- Kidney disease should be assessed before, as contrast materials or dyes may not be used in patients with abnormal kidney function.
- Some blood tests and electrocardiogram (ECG) will be performed before the procedure.
- A mild sedative will be given orally or intravenously to comfort the patient and relieve anxiety.
- All personal belongings and jewellery will be removed and patient will be dressed in a hospital gown before being transported to the catheterization laboratory. [17]

PROCEDURE

Introducing the catheter into the artery

Radiologist or doctor cleans the skin by sterile materials own place insert the catheter and by the fact that usually in the top pagan thigh or pagan arm. After cleaning the doctor injects a small amount of local anesthetic so that the patient does not feel any pain. And pays the doctor a catheter tube to the scene to be filmed scans show where the catheter tube on Star TV caller-ray device and does not feel at all over the catheter in his arteries.

Colure injection

When a party up to the catheter tube required photographed achieve article colorful and at the same time begins radiography. The patient will feel when injected material colored with some heat in his body for a period of a few seconds. Usually colored material is injected in batches accompanied by taking X-rays until the complete imaging process in an integrated film showing what has been filmed.

With drawn from the artery catheter tube

This is done after the completion of radiographic examination and pull the tube does not cause any pain and place insert the tube and Shabheptm pressure on that place for ten to twenty minutes to prevent blood being in the artery of the rush to the outside that process catheter entire take from half an hour to one hour, but in some sometimes more than that, especially if the doctor decided that addresses place artery occlusion expand it or inject drugs to dissolve blood clots if any.

Risk complication

The overall risk for complications from cardiac catheterization is about 1 in 1000. Contrast dyes because adverse affects in almost 1 out of 10 patients. The common side effect is nausea or vomiting. Some of the complications due to dye allergy are.

- Fast heartbeat
- Slow heartbeat
- Nausea
- Vomiting
- Shock
- Kidney failure
- Epilepsy
- Itching
- Rashes

Few other complications

- Bleeding at the insertion site
- Damage to the blood vessels used for catheter entry
- Infection
- Ventricular arrhythmias
- Pneumothorax [air collection between the chest wall and the lungs]
- Cardiac tamponade [fluid collection around the heart]
- Heart attack
- Stroke [0.1%]
- Air embolism
- Death [0.1- 0.2%]

In rare cases, patients undergoing angiogram will be shifted to the operation room for an emergency bypass surgery. [17]

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.

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

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.

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.

RESULTS

Patient's measurements

The results were tabulated in the Tables (mean ± standard deviation (sd)) and the range of the readings in parenthesis. The mean and the standard deviation were calculated using the excel software & SPSS program. For dose calculation, patient individual exposure parameters were recorded (tube voltage (kV), tube current and exposure time product (mAs). Patient demographic data (age, height, weight, BMI) were presented.

The correlation coefficient which is defined as a measure of the degree of linear relationship between two variables, usually labeled X and Y used in this study to describe the relation between two variables affect patient dose ESD(mGy) against tube current time product(mAs) and tube voltage (kV) and flouro time (minute). Positive correlation coefficients were obtained between these values. This means if the value of mAs or kV increases the value of the ESD increases.

Table 2: Gender patient total dose in Khartoum Teaching Hospital

Examination	Total sample	Flouro time	Cini time(S)	DAP(GY. Cm2)
CA	87	5.31	5.31	6703.5
PCI	21	7.00	57.65	8083.8

Table 3: Dosimetric Measurements per Type of Intervention

Variable	ESD	DAP
Male	74.87±41.33 (9.75-226.84)	74.86.8±4132.96 (975.39-22684.27)
Female	72.52±27.91 (37.60-157.30)	7252.3±2791.25 (3760.09-15729.92)
Total	73.84±35.74 (9.75-226.84)	7384.2±3574.69 (975.39-22684.27)

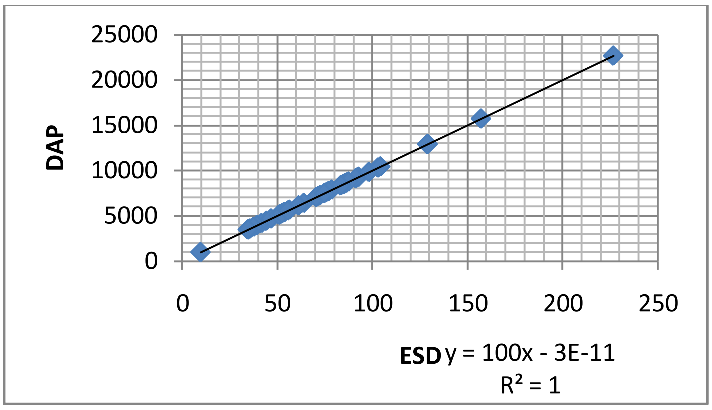

Fig 1: correlation between entrance skins dose ESD (mGy) and DAP (Gy.cm^2)

DISCUSSION

It is evident from the tabulated data that the range of the reported values for each IC procedure is considerably wide. For example the range of DAP values for CA (1.1- 2400Gy·cm2) comprises the DAP values reported for almost any IC procedure. This is however due to the fact the CA is the most extensively studied procedure and dosimetric data include results reported in the 80s and 90s when radiation protection and catheterization laboratory equipment were less advanced. A recent study collected DAP values for 2265coronary angiographies performed between 2003-2005 in seven centers and has also reported large variability of results although DAP values spanned in narrower range of 5-130 Gy·cm2. [19] The wide range of reported values are evident in all IC procedures and can be attributed to operator experience [20], workload [21], use of radiation-reducing techniques [20], procedural complexity , examination technique and catheterization laboratory equipment . In order to compare results between older and newer studies, mean DAP, mean fluoroscopy time and mean effective dose were calculated for results published before and after the year 2000 concerning the most extensively studied procedures (CA and PCI) (Table 4). It is evident that due to on- going development in radiation protection and catheterization laboratory equipment there is considerable reduction in radiation received by patients.

Table 4: Comparison of results between Studies Published before and after the Year 2000

Quantites	Flouruscopy time (min)		DAP (GY.Cm)2	
Examination	CA	PCI	CA	PCI
Before year 2000	6.2	21.3	52.5	81.7
After year 2000	3.7	12.2	31.1	59.2

The calculated mean values of the dosimetric and non dosimetric quantities indicate that PCI procedures either with or without stent implantation result in increased radiation received by patients compared to angiography. A total of 48 adults patients were examined in the Khartoum teaching hospital ,29 patient are Exposure in (CA) ,and 7 in (P C I) table (3) , Bernardi *et al.;* [22] and Padovani *et al.;* [23] investigated the effect of the complexity of PCI procedures on patient exposure by dividing the procedures in 'simple', 'medium' and 'complex' based on a set of indexes and they found correlation between patient dose and procedural complexity , after compare with above study there are variations and increase in dose. The major cause of this increase in the radiation dose was that our subjects included many patients with complex heart disease that lead to prolong fluoroscopy time, and also was that of old age of tube in fluoroscopy machine that lead to increase MA and kVp. The mean of age, weight, and height and body mass index to the patients are 56.81, 67.24, 162.85 and 25.22 respectively.

The mean of kVp, mAs, SID, number of exposure per week, cini second, flouro time and total dose are 84.64, 3647.80, 109.24, 4.10, 58.78, AND 785.05 respectively. in this study ,there are a good correlation between entrance skin dose ESD (mGy) and (dose area product (GY.Cm2) (r2 =1) , there are a poor correlation between entrance skin dose ESD (mGy) and fluoroscopic time in minute (r2=0.151) ,and poor correlation between entrance skin dose ESD (mGy) and tube potential kVp (kV) into Fluoroscopy (r2 = 0.606) ,and there are a poor correlation between entrance skin dose ESD (mGy) and the product of the tube current (mAs) (r2 =0.397) .

CONCLUSIONS

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

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