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Factors Affecting the Optimal Radiation Dose and Image Quality During Cardiac Catheterization Procedures

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ABSTRACT

The purpose of this study is to clarify the factors affecting the dose of radiation exposed to the patient during cardiac catheterization procedures, optimal dose measurement while maintaining image quality, and how to avoid the risk of radiation. 188 heart catheters were performed for elderly patients in two cardiology centres, Wad Medani Heart diseases &surgery Centre (WHC) during the period (2017 - 2018 and the Sudanese Heart Centre (SHC) from August to September 2018, All the machines used in the study have passed the quality control tests conducted by the Sudanese Atomic Energy Commission (SAEC), The study found that the optimal radiation dose depends on a number of factors, the number of frames (Fr), number of films (N.F), fluoroscopy time(FT), KVp, ms, BMI, SID, type of procedure and clinical indication, to reduce the radiation risk and achieve the optimal dose and maintain the lowest possible level recommended the study to apply the largest possible distance(SID) and the minimum number of frames and the number of films, fluoroscopy time and follow up all procedures high precision and training of doctors and radiologist. Along with the development of physician methods and skills, we suggest planning a specific program before the procedure and this helps to reduce radiation dose and avoid radiation risk.

Keywords: radiation, radiation dose, biological effects, Angiography, Cardiac catheterization.

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INTRODUCTION

Radiation is an energy that travels through space or matter. There are two types of ionizing radiation used in medical imaging: electromagnetic radiation (EM) and particles.

Electromagnetic radiation (gamma rays and x-rays) Radiography is used in vascular imaging (diagnostic and therapeutic cardiac procedure, Absorbed dose, measured in grays (Gy), quantifies the energy deposited per unit mass. The energy deposition of 1 J/kg of tissue is the equivalent of 1 Gy. Because not all types of radiation produce the same biological effect, the dose equivalent is often used instead of the absorbed dose. The dose equivalent is the product of the absorbed dose and a radiation weighting factor and is expressed in sieverts (Sv). Because the radiation weighting factor for x-rays and gamma rays is 1.0, 1 Gy is equivalent to 1 Sv in medical imaging. Radiation doses in medical imaging are typically expressed as millisieverts (mSv).

when the patient is exposed to X-rays, they lead to biological effects of the organism (occurring in the patient exposed to radiation) or genetic effects (occurring in the generations of the patient as a result of radiation damage to the genitals of the patient exposed to radiation) , There are two types of biological effects of radiation are the deterministic effects of radiation (occurring when exposure to high doses of radiation, which leads to damage to the body's cells or damage to the central nervous system(CNS)) ,stochastic effects (including cancer and genetic risk). The risk of deterministic and stochastic risk increases with increased dose and other factors. The small doses that workers receive during their work can lead to harmful effects in the long term called late effects.

Angiography is the imaging of blood vessels after a contrast medium has been injected into the bloodstream that shows up on live X-ray pictures. A liquid contrast agent (sometimes called contrast medium) Iodine-containing contrast medium (ICCM) is injected into an artery or vein. This increases the density of the blood in the vessels and allows a clear X-ray image or picture. Angiograms are a special kind of x-ray picture that shows what is happening inside the blood vessels. They help show blood vessel abnormalities such as narrow, occlusion (blockage), or bleeding. Angiograms also may be performed to guide treatment. After inserting a tiny plastic tube into a blood vessel to make the angiogram pictures, this same tube can be used to place a tiny balloon into the artery, if it is too narrow, to widen it and allow normal blood flow. This procedure is called angioplasty. Occasionally a stent (a tiny piece of metal tubing) might be put inside the narrowed area along with the balloon to keep the blood vessel open.

Table 1: X-ray machine characteristics

Hospital	X-ray(Model)	Filtration	kVpmax	mAs Max	Last image hold	Puls fluoro	Date of installation
SHC	PHILIPS Integris V5000	3.5 mm Cu	125		YES	YES	1998
WMHC	Philips (Allura X per FD 10)	2.5 mm Al	150	1250	YES	YES	2011

Imaging cardiac catheters procedures are an important source of exposure to ionizing radiation in the Sudan and can result in high cumulative effective doses of radiation. The patient during heart catheterization procedures, This study was conducted in two centres of heart disease in Sudan (Wad Medani Heart diseases &surgery Centre (WHC) and Sudan Heart Centre (SHC)). The study was conducted in the centre of (WHC) during the period (2017 - 2018), where 135 heart catheters for the elderly, including 54 females (40%) and 81 males (60%), which are 69 diagnostic catheters (51.1%), 29 treatment (21.5%) And 37 cardiac pacemakers (27.4%). The heart centre of Sudan(SHC) in August to September 2018, where 53 heart catheters were performed for the elderly, including 20 females (37.7) and 33 males (62.3), 36 diagnostic catheters (67.9)), 10 therapeutic (18.9%) and 7 cardiac pacemakers (13.2%). All X-ray devices used in these tests were calibrated by the Institute for Radiological Safety (IRS) of the Sudanese Atomic Energy Commission (SAEC).

In (WHC) , mean and range age of patients (year), height (cm), weight (kg) and body mass index (Kg / m2): 62.7(32-90), 162(150-184), 76.8(55-103), 29.2(21.1-35.9), respectively, While the mean and range potential, current and time for tube , 83.3(64-105)KVp, 746.6(377-865)mA, 6.9(3-9)ms, respectively and range number of films per procedure is 9.7 (2-32) and the mean and range fluoroscopy time was 4.4(1-31.4)min. The mean and range of source to image detector distance (SID) per procedure was 117.4(112-122)cm, mean ,range of cumulative area dose (CAD) in this study is 783.2(99.7-4433.7)mGy, and dose area product(DAP) is 54.7(9.4-262.1) Gy m2 .

In Sudan Heart Centre, Mean and average age of patients (year), height (cm), weight (kg) and body mass index (Kg/m2): 59.4(33-87), 162.3(154-182), 73.1(54-105), 27.8(21.1-39.5) respectively, while the mean and range exposure parameters were 81.4(72-99) kVp, 341.3(74-491) mA and 6.7(2.4-10.6)ms for tub potential, current and time tube, respectively, mean and range of source to image detector distance (SID) is 112.8(104-120), the average and range of number of films is 8.4(0-22), average fluoroscopy time was 6.5(1-33.6). The average and the number of frames per procedure was 470.1(0-1036), mean and range of dose area product

(DAP-Gy.cm2), cumulative air karma (CAK-mGy) is 4541.9(269.4-24877.2) Gy cm2, 368(26.6-1497.2)mGy, respectively.

The study found that the optimal radiation dose depends on a number of factors such as frame number(Fr), number of films(NF), fluoroscopy time (FT), KVp, ms, BMI, SID, type of procedure and clinical indicator. The study presented a number of recommendations and proposals to reduce radiation risk and achieve optimal dose.

MATERIALS AND METHOD

Cardiac catheterization was performed for 135 patients at the (WHC) and 53 patients at the (SHC). Data were collected on the demographic information of the patients, the technical parameters, the mean and the range of the patient's catheter doses during the period (2017-2018), in (WHC) during the period from Augusts to September 2018 in (SHC), All the machen used in the have passed the quality control tests conducted by the Sudanese Atomic Energy Commission (SAEC), We used the Scale length to measure patient length (cm), Weighing scale to study measure patient weight (kg), Two monitors for the catheterization device in the control room for the catheterization procedure recorded from it namely dose area product (DAP-Gy.cm^2), cumulative air kerma (CAK-mGy) were measured during data collecting. The data collected also number of frames, number of films, and total fluoroscopic time (FT). Exposure factors as kVp and mA also collected as well as procedure type, The required measurement values were recorded, some of them practically and directly, from digital devices and equipment.

RESULTS AND DISCUSSION

Monitored the Mean and range of demographic data for adult patients undergoing CAD, PCM, PCI in table 2,3,4,5.

Table 2: Gender & Number of patients and percentage of each procedure in (WHC, SHC)

HOS	N. P	N. Female(%)	N. Male (%)	CAD (N.P%)	PCI (N.P%)	PCM (N.P%)
WHC	135	54 (40%)	81 (60%)	69 (51.1%)	29 (21.5%)	37 (27.4%)
SHC	53	20 (37.7%)	33 (62.3%)	36 (67.9%)	10 (18.9%)	7 (13.2%)

Table 3: Mean and range of demographic data for adult patients undergoing Coronary Angiography Diagnostic (CAD) procedures

Hospital	No. P	Age (Y)	Height (cm)	Weight(kg)	BMI(kg/m^2)
WMHC	69	59.4(32-90)	162(151-178)	77.5(55-93)	29.4(21.1-35.9)
SHC	36	55.9(33-79)	161.8(154-182)	73.8(55-105)	28.2(22-39.5)

Table 4: Mean and range of demographic data for adult patients undergoing Pacemaker (PCM) procedures

Hospital	No.P	Age (Y)	Height (cm)	Weight(kg)	BMI(kg/m^2)
WMHC	37	65.2(52-80)	161.4(150-184)	74(65-92)	28.5(24.3-33.6)
SHC	7	71(52-87)	160.9(160.9-157)	68.7(54-85)	26.6(21-33.6)

Table 5: Mean and range of demographic data for adult patients undergoing Therapeutic Catheter (PCI) procedures

Hospital	No. P	Age (Y)	Height (cm)	Weight(kg)	BMI(kg/m^2)
WMHC	29	67.3(35-80)	162.8(155-181)	78.6(67-103)	29.6(62.1-34.5)
SHC	10	61.2(43-80)	164.8(157-177)	73.1(62-78)	26.9(29.6-23.3)

In (WHC) we found The mean and range of BMI 69(51.1%) adult patients undergoing coronary Angiography Diagnostic(CAD) procedure for clinical indication (STEMI or NOSTEMI) is found 29.4(21-35.9) kg/m^2 it is overweight, 29 (21.5%) adult patients undergoing Percutaneous Coronary Intervention (PCI), is found 29.6(26-34.5) kg/m^2 it is overweight, 37(27.4%) adult patients undergoing pacemaker (PCM) procedure is found 28.5(24.3-33.6)kg/m^2 it is overweight, In (SHC)we found The mean and range of BMI 36(67.9%) adult patients undergoing coronary Angiography Diagnostic(CAD) procedure for clinical indication is found 28.3(22-39.5) kg/m^2 it is overweight, 10 (18.9%) adult patients undergoing Percutaneous Coronary Intervention (PCI), is found 26.9(23-29.6) kg/m^2 it is overweight, 7(13.2%) adult patients undergoing pacemaker (PCM) procedure is found 26.6(21-31.6)kg/m^2 it is overweight, Table 6, show the Comparison between BMI values of patients and WHO values for two hospital(WHC & SHC).

Table 6: Comparison between BMI values of patients and WHO values for two hospital

Hospital	Procedure	N. Patients	BMI (kg/m^2)	BMI (IHO) Category
WHC		69	29.4(21.1-35.9)	
SHC	CAD	36	28.32(22.03-39.52)	Over weight
WHC		29	29.6(62.1-34.5)	
SHC	PCI	10	26.94(23.34-29.62)	Over weight
WHC		37	28.5(24.3-33.6)	
SHC	PCM	7	26.56(21.09-33.6)	Over weight

Table 7: Mean and range of technique parameters for adult patients undergoing Coronary Angiography Diagnostic (CAD) procedures

HOS	N.P	kVp	Ma	ms	Fluoro Time	SID	N.F
WHC	69	83.9(64-105)	759(455-865)	7(5-8.7)	3.5(1.1-26.2)	117(112-122)	10.3(5-16)
SHC	36	83.9(72-99)	370(196-491)	6.9(4.5-9)	4.9(1-16)	112.8(104-119)	7.7(3-13)

Table 8: Mean and range of technique parameters for adult patients undergoing Pacemaker (PCM) procedures

HOS	N.P	kVp	mA	ms	Fluoro Time	SID	N.Flem
WHC	37	79.6(66-95)	729(377-838)	6.4(3-8.4)	2.5(1-7.5)	120(116-122)	5.2(2-9)
SHC	7	75(72-80)	244(177-375)	3.8(6.4-2.4)	8.3(3.7-27.3)	113.6(104-119)	3.3(0-10)

Table 9: Mean and range of technique parameters for patients undergoing (PCI) procedures

HOS	N.P	kVp	mA	ms	FluoroTime	SID	N.F
WHC	29	86.9(72-103)	740(621-804)	7.3(5.6-9)	8.8(2-31.4)	114.7(112-117)	14(7-32)
SHC	10	80.4(73-95)	367(201-485)	7.2(6-9.6)	10.9(1.4-33.6)	113(108-117)	13(8-22)

Table7,8,9, show the Mean and range of technique parameters for adult patients undergoing Coronary ,CAD,PCM.PCI, procedures,

Table 10: (CA mGy and CAD Gy.cm^2) Mean and range for procedures performed at WHC

Procedure	N.P	CA mGy	DAP Gy.cm^2
CAD	69	722.9(121-1450)	50.5(23-118)
PM	37	390(99.7-668)	24.6(9-39)
PCI	29	1427.9(336-4434)	102.9(22.3-262.1)

Table.11: (CA and CAD Gy.cm^2) Mean and range for procedures performed at SHC

Procedure	N.P	CAk mGy	DAP Gy.cm^2
CAD	36	335.5 (76.7-636)	44.5(2.7–248.8)
PM	7	123.8 (26.6-365.2)	24.5(10.1 – 55.4)
PCI	10	682.4 (172.5-1497.2)	70.9(13.4–151.1)

Table10,11 show the Mean and range of (CA and DAP Gy.cm2) for procedures performed at SHC &WHC,

Table 12: Comparison between mean and range for BMI values of patients and (CAD Gy.cm^2) for procedures performed at WHC & SHC

HOS	Procedure	N.P	BMI	DAP Gy.cm^2
SHC	CAD	36	28.32(22.03-39.52)	44.5(2.7–248.8)
WHC		69	29.4(21.1-35.9)	50.5(23-118)
SHC	PCI	10	26.9(23.34-29.62)	70.9(13.4-151.1)
WHC		29	29.6(62.1-34.5)	102.9(22.3-262.1)
SHC	PCM	7	26.6(21.09-33.6)	24.5(10.1 – 55.4)
		37	28.5(24.3-33.6)	24.6(9-39)

Table.12, show the: Comparison between mean and range for BMI values of patients and (CAD Gy.cm2) for procedures performed at WHC & SHC,

Table 13: Comparison between mean and range for fluoroscopy time(FT) & SID, N.F, N.Fr values and (CAD Gy.cm^2) for procedures performed at WHC & SHC

HOS	Procedure	N.P	N.F	N.Fr	(FT)min	SIDcm	DAP Gy.cm^2
SHC	CAD	36	7.7(3-13)	455.8(231-747)	4.9(1-16)	112.8(104-119)	44.5(2.7–248.8)
WHC		69	10.3(5-16)	-	3.5(1.1-26.2)	117(112-122)	50.5(23-118)
SHC	PCI	10	13(8-22)	727(409-1036)	10.9(1.4-33.6)	113(108-117)	70.9(13.4-151.1)
WHC		29	14(7-32)	-	8.8(2-31.3)	114.7(112-117)	102.9(22.3-262.1)
SHC	PCM	7	3.3(0-10)	195.4(0-824)	8.3(3.7-27.3)	113.6(104-119)	24.5(10.1 – 55.4)
WHC		37	5.2(2-9)	-	2.5(1-7.5)	120(116-122)	24.6(9-39)

Table.13, show the Comparison between mean and range for (fluoroscopy time(FT) & SID, N.F, N.Fr values) and (CAD Gy.cm2) for procedures performed at WHC & SHC,

Table 14: Comparison between mean and range for (KVp, mA, ms) values and (CAD Gy.cm^2) for procedures performed at WHC & SHC

HOS	Procedure	N.P	KVp	mA	ms	DAP Gy.cm^2
SHC	CAD	36	83.9(72-99)	370(196-491)	6.9(4.5-9)	44.5(2.7–248.8)
WHC		69	83.9(64-105)	759(455-865)	7(5-8.7)	50.5(23-118)
SHC	PCI	10	80.4(73-95)	367(201-485)	7.2(6-9.6)	70.9(13.4–151.1)
WHC		29	86.9(72-103)	740(621-804)	7.3(5.6-9)	102.9(22.3-262.1)
SHC	PCM	7	75(72-80)	244(177-375)	3.8(6.4-2.4)	24.5(10.1 – 55.4)
		37	79.6(66-95)	729(377-838)	6.4(3-8.4)	24.6(9-39)

Table.14, show Comparison between mean and range for (KVp, mA, ms) values and (CAD Gy.cm2) for procedures performed at WHC & SHC.

From Table.10,11 we found that the dose in the therapeutic catheterization(PCI) was higher than the diagnostic (CAD) and lower when the pacemaker(PCM), This indicates that the optimal radiation dose and image quality depend on the type of procedures figure1,

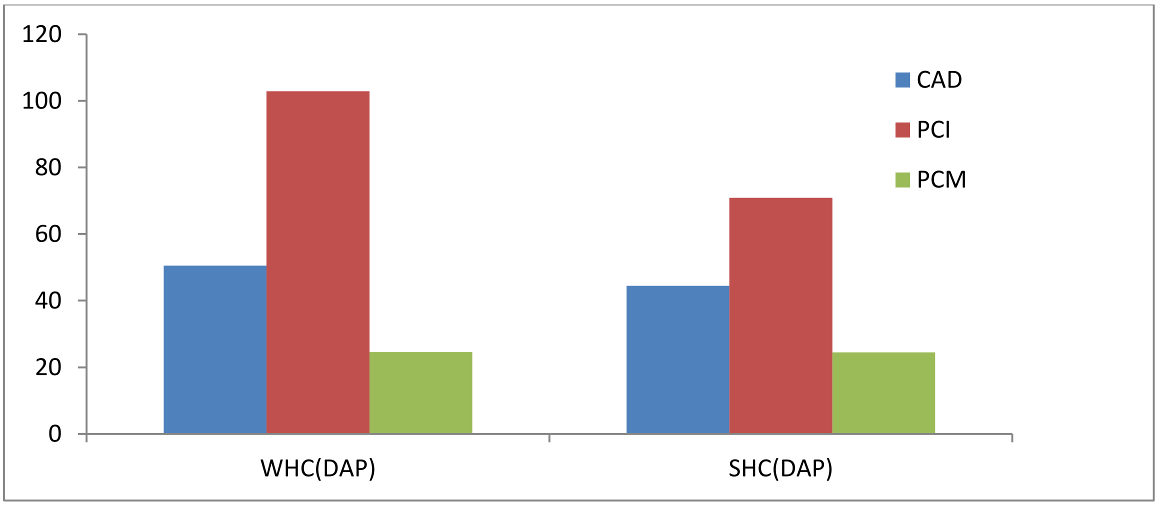

Figure 1: Comparison between mean of (CAD Gy.cm^2) and type of procedures performed at WHC & SHC

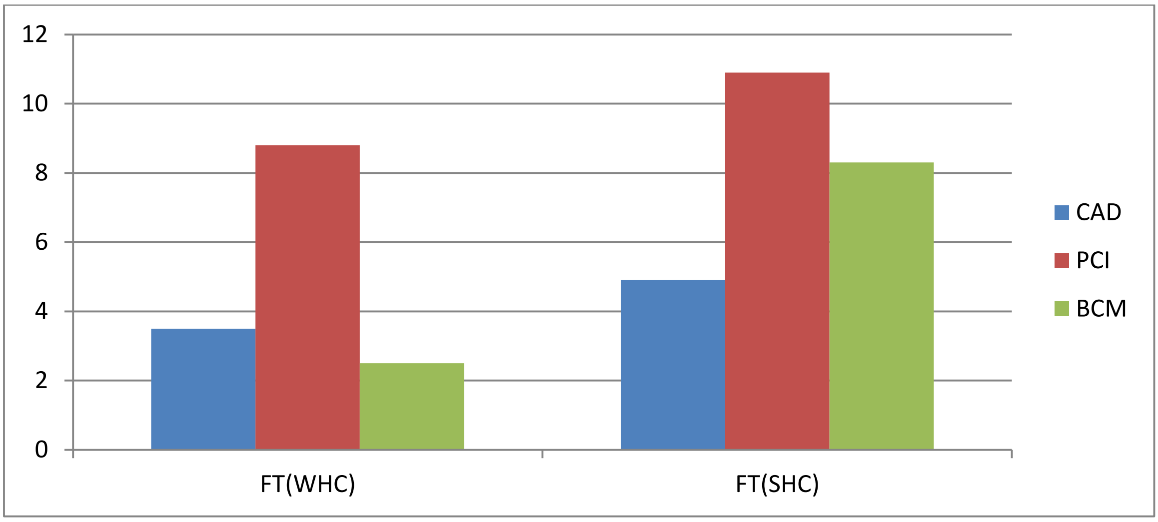

Figure 2 :Comparison between mean of fluoroscopy time (FT) and type of procedures performed at WHC & SHC

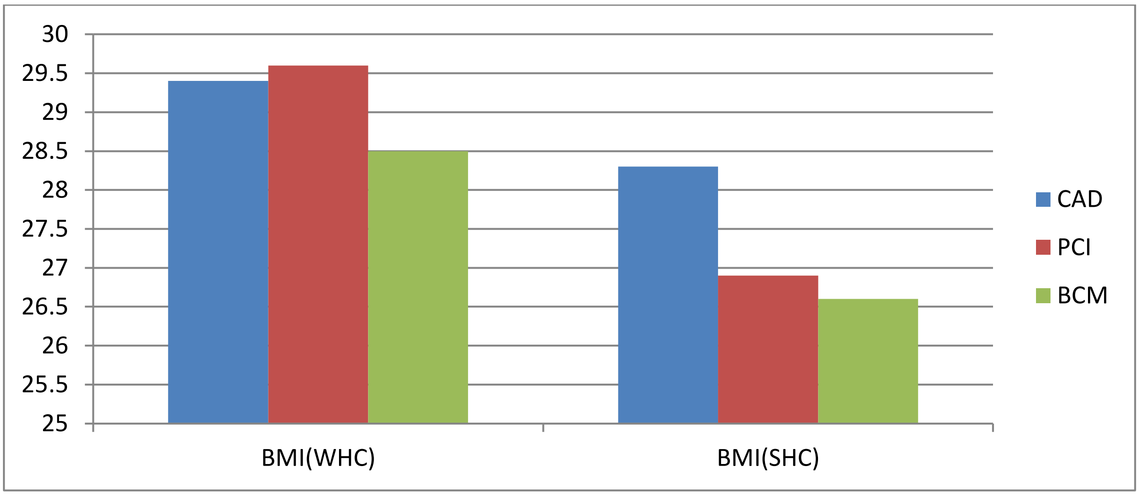

Figure 3 : Comparison between mean of BMI and type of procedures performed at WHC & SHC

In Table 12 and Figure 3, we found that there was a relationship between the type of procedure and the body mass index, and by reference to Figure 1 we conclude that the dose increased by increasing BMI. This is a second indicator that BMI affects the radiation dose. The image quality is better if specific x-ray programs are used for patients of different sizes (patients with obesity receiving a higher dose of thinness). Table 13, indicating that the values of the source to the image - the distance of the receiver (SID) is small for catheter values Diagnostic and therapeutic, while increasing slightly when conducting a regulator Pat heart. This confirms the inverse ratio between (DAP) and (SID),

Figure 8.From Table 14, a relationship was found between the KVp, and ms of the X-ray tube and the dose(DAP),

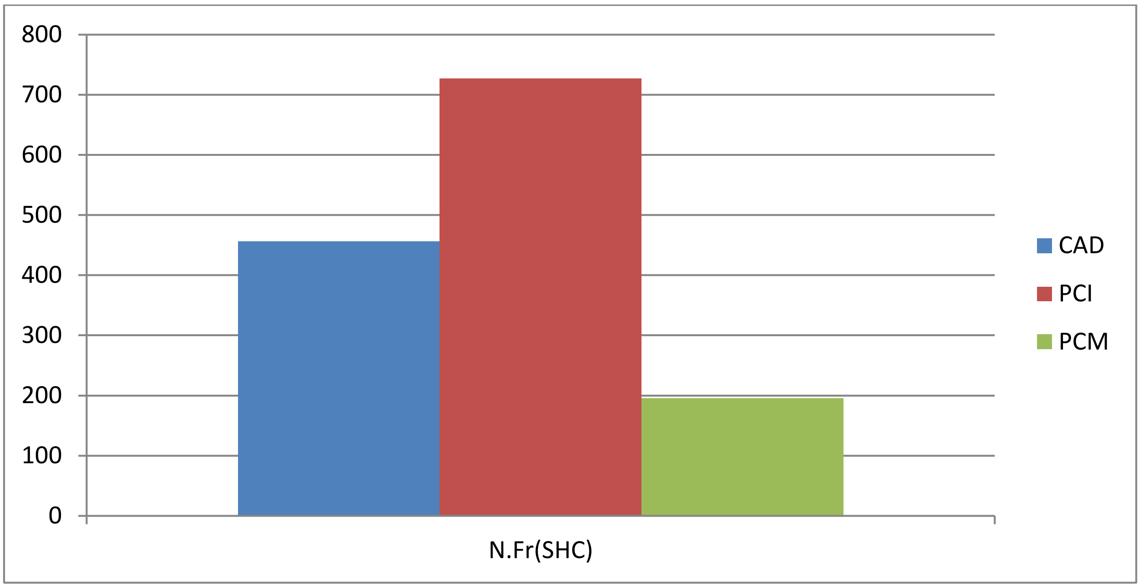

Figure.4 : Comparison between mean of number of frame (N.Fr) procedures performed at WHC & SHC.

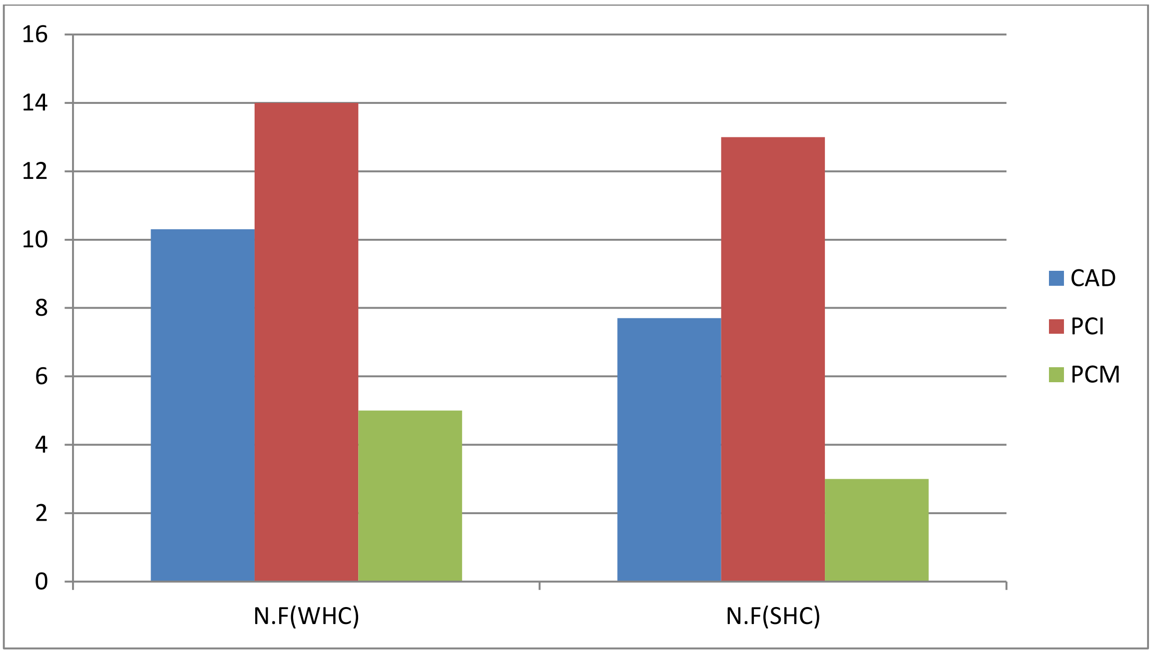

Figure 5: Comparison between mean of number of film (N.F)and type of procedures performed at WHC & SHC

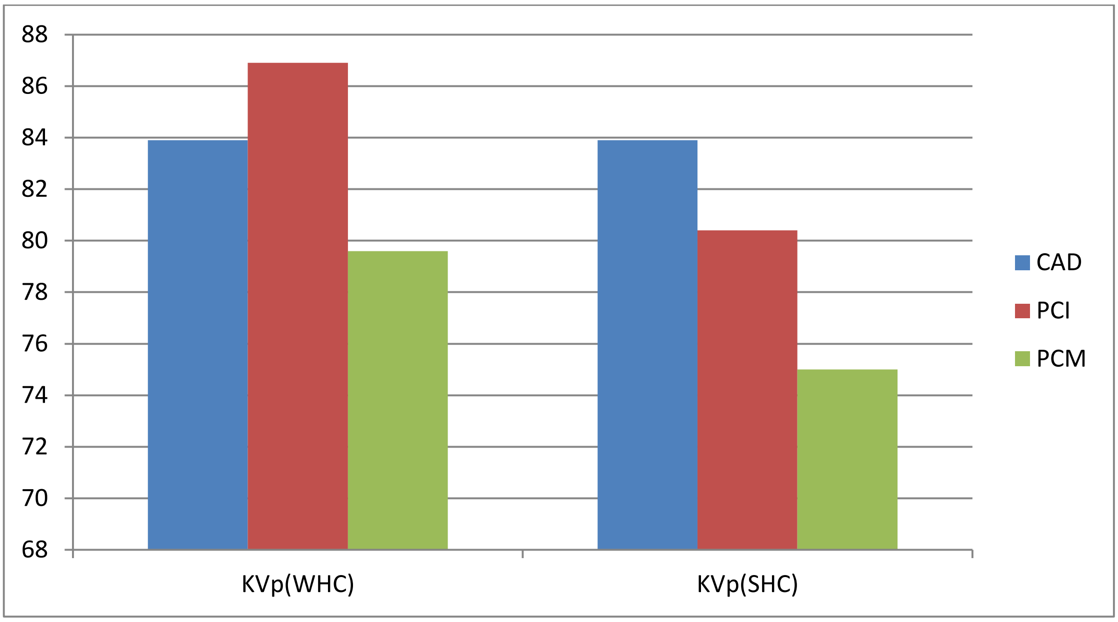

Figure 6 : Comparison between mean of KVp and type of procedures performed at WHC & SHC

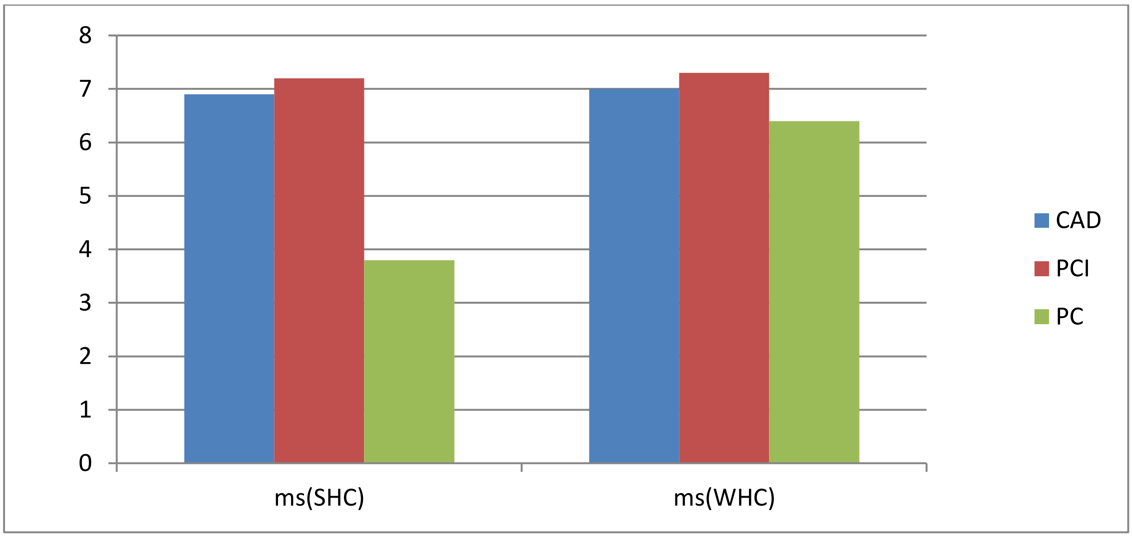

Figure 7 : Comparison between mean of MS and type of procedures performed at WHC & SHC

figures.6,7 is show the relation. The study found in both hospitals the number of patients who underwent cardiac catheterization were men without women, show figures.(9,10).

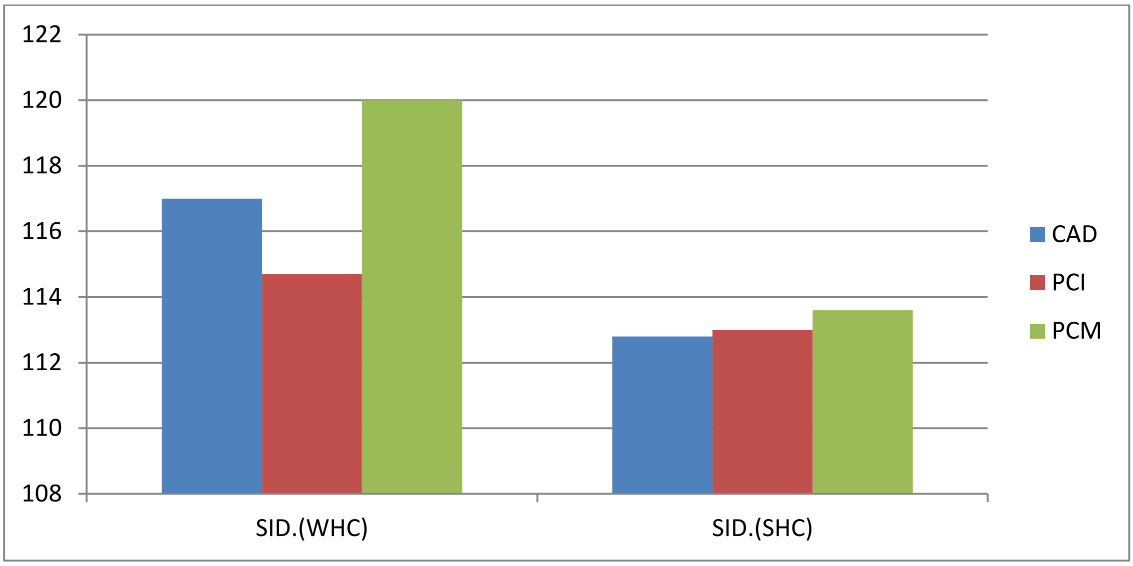

Figure 8 : Comparison between mean of SID and type of procedures performed at WHC & SHC

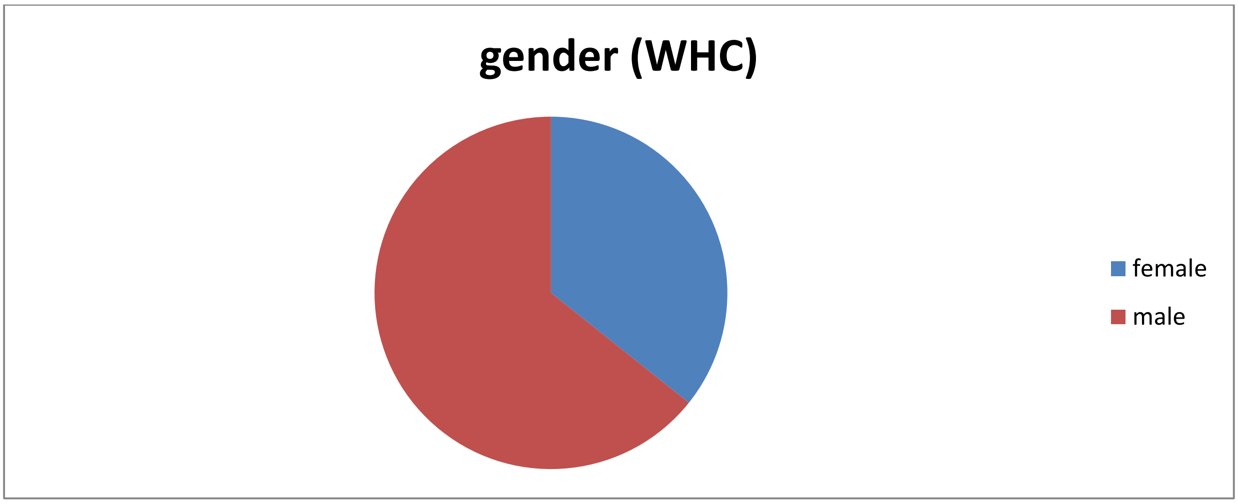

Figure 9 : Comparison between number of male & female 1n WHC

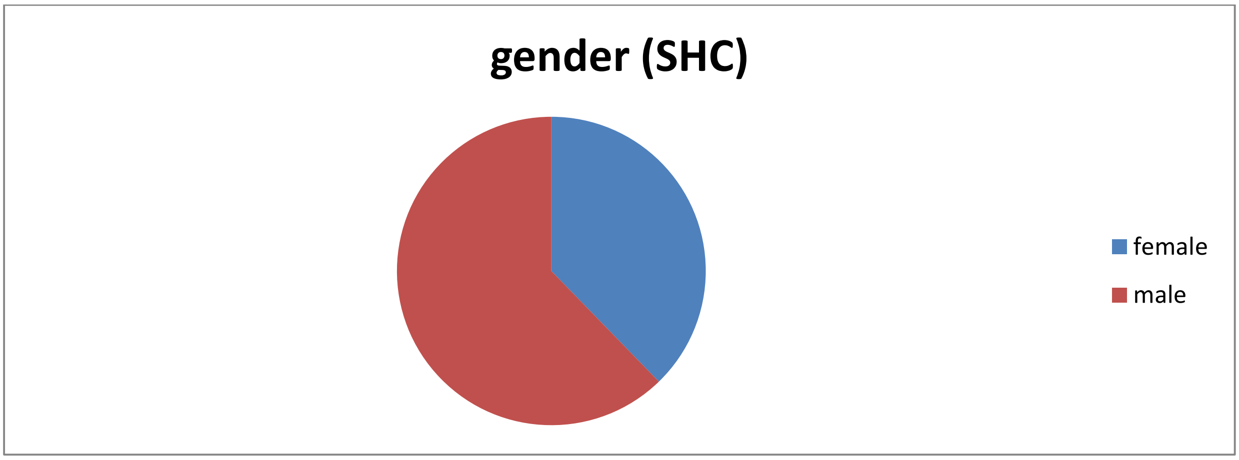

Figure 10 : Comparison between number of male & female 1n SHC

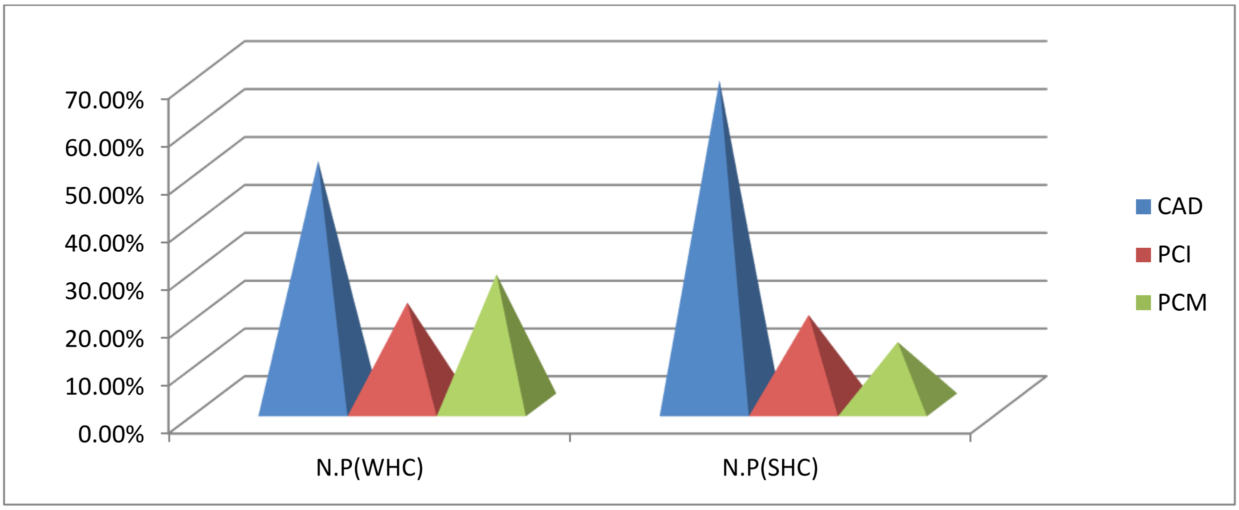

Figure 11: Comparison between WHC & SHC

The results of our study agreed with Vanot. et al 2014, that the type of the procedure, the BMI of patient and the experience of the cardiologist performing the procedures all affect the DAP, and agree with George et al 2007, and with the results of the Kuon et al 2004 that fluoroscopy time is an effective factor in evaluating the DAP.

CONCLUSION

In Sudan, the patient is first subject to diagnostic catheterization and then to therapeutic catheterization (because of the high cost of operation and poor patient) This doubles the patient's exposure to radiation, There are some educational hospitals that allow less experienced physicians to practice heart operations and lack a trained crew and are aware of radiation risks, for these factors the patient is exposed to high radiation dose. This study was carried out to help avoid the risk of radiation and determine some of the factors contributing to the increase in dose of radiation.

This study was conducted in two different locations. Despite the differences in the number of patients, clinical indication, procedure type and the differences in the abilities of the staff who performed the operation, the results did not differ significantly. The presence of a large variability in the entrance surface air kerma rates for both fluoroscopy and image acquisition modes .The study found that the optimal cumulative dose of radiation (DAP) depends on some factors. Including patient size, equipment, technique and procedure type, there are factors directly proportional to the product of the accumulated dose area, such as exposure time (FT), number of films (NF), number of frames (N.Fr) and body mass index (BMI) On the distance.

Our study indicates that there is variation in dap due to different methods of endoscopy and image acquisition.

We strongly recommend that we set up such procedures in the large distance(SID), recommend reducing fluoro time, number of frame, Use stored images instead of the directly images to clarify the diagnosis, avoid magnification to reduce exposure to radiation, all the staff inside the catheter must be wearing a protective shield, educate all those working inside the catheterization room to the seriousness of radiation and how to reduce the dose of radiation, we also recommend intensifying research and reaching accurate results that unify the points of contention and support the avoidance of risk.

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