THE DETERMINATION OF THE AVERAGE PATIENT SKIN DOSE AND ITS FACTORS AFFECTING IN CARDIAC CATHETERIZATION PROCEDURES

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ABSTRACT

The patient dosimetry for cardiac catheterization and its factors affecting in this study were determined using Dose Area Product (DAP) method. The skin dose was calculated from DAP meter readout and information from portal film determination. Factors affecting patient dose are fluoroscopy time, patient body mass index (BMI), kVp, mAs, experience of the cardiologists, number of frames and etc. The measurement was carried out from 73 patients who underwent the cardiac catheterization procedures examination such as Diagnostic Coronary Angiography (DCA), Cardiac intervention; Percutaneous Transluminal Coronary Angioplasty (PTCA)/stent and cardiac radiofrequency ablation at King Chulalongkorn Memorial Hospital. The result of the average patient skin dose from DCA was 9.52 cGy in tube A (Postero-Anterior) and 18.67 cGy in tube B (Lateral), PTCA/stent 35.95 cGy in tube A and 85.42 cGy in tube B and cardiac radiofrequency ablation 64.82 cGy for single plane. The patient skin dose is more dependent on the fluoroscopy time than other factors. The patient skin dose and the fluoroscopy time was well correlated for RF ablation ($r = 0.90$), PTCA/stent ($r = 0.83$) and DCA ($r = 0.60$). The average patient skin doses in this study were less than threshold dose of skin injury (2Gy). Only two patients received the dose higher than the threshold dose (2.12, 4.51Gy) from cardiac radiofrequency ablation and cardiac interventional studies respectively. The benefit of this study are reported and established the patient skin dose in order to protect the patient from skin injury and increase the cardiologists, awareness for cardiac catheterization procedure.

Keywords: Patient skin dose, Cardiac catheterization procedures

BMI = Body Mass Index, **DAP** = Dose Area Product
DCA = Diagnostic Coronary Angiography
PTCA = Percutaneous Transluminal Coronary Angioplasty

INTRODUCTION

Cardiac catheterization procedures such as Diagnostic Coronary Angiography (DCA), Cardiac Intervention; Percutaneous Transluminal Coronary Angioplasty (PTCA)/Stent and Cardiac Radiofrequency Ablation have lower risks than surgical procedures and their wide acceptance has led to an increasing number being performed.[1] The extensive use of this procedure increases risk of radiation induced effects in patients. The highest entrance skin dose may be harmful as skin injuries. Two types of radiation effect may occur are deterministic and stochastic effects. The risk for long-term stochastic effects may be

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assessed by effective dose.[2] The majority of instances reported by the United States Food and Drug Administration (FDA) results from cardiac radio frequency ablation and coronary angioplasty.[3-4] The FDA, the World Health Organization (WHO), the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) published documents[5-6] to avoid deterministic effects in cardiology procedures. There is now general agreement that the patient skin dose should be determined if there is a risk that doses approach or exceed the threshold levels for deterministic effects. A threshold level of concern is 2 Gray (Gy) for the onset of transient erythema and 3 Gy for hair loss.[5,7] Cardiologists should be aware of potential for serious radiation induced skin injury caused by long periods of fluoroscopy occurring with some of these procedures. Further from patient skin dose, the procedure complexity and factors affecting patient skin dose are very important factors for evaluation during procedures. In September 1995, FDA of the United States issued a public health advisory entitled *Avoidance of Serious X-rays Induced Skin Injuries to Patients during Fluoroscopy-Guided Procedure*.[8] The advisory recommended, among several items, that information be recorded in the patient's record which permits estimation of absorbed dose to the skin. The purpose of the recommendation is to encourage identification of those areas of the skin which are irradiated at levels of absorbed dose that approach or exceed a threshold for injury.[9] In this study, the patient skin dose is measured using Dose Area Product (DAP) dosemeter, where the detector is placed on the collimator of the X-ray tube. The readout data from the meter is in the unit of cGy.cm^2. The patient skin dose (cGy) is determined from the calculation when the radiation area in cm^2 is obtained. The radiation area is determined from the verification films used in the radiation therapy. Film is placed on the couch under the patient and exposed for the whole examination.

The objective of this study is to evaluate the average patient skin dose in each procedures and factors (kV, mAs, fluoroscopy time, patient body mass index (BMI), number of frames, number of procedures and etc.) affecting patient skin dose during cardiac catheterization procedures.

FDA = United States Food and Drugs Administration
WHO = World Health Organization
ICRP = International Commission on Radiological Protection
IAEA = International Atomic Energy Agency
GY = Gray
DAP = Dose Area Product
EAP = Exposure Area Product

MATERIALS AND METHODS

MATERIALS

A. Radiographic-Fluoroscopic system

Table1 The x-ray machines used for cardiac catheterization.

Procedures	Manufacturer	Model / Year
Diagnostic Coronary Angiography (DCA), Cardiac intervention; Percutaneous Transluminal Coronary Angioplasty (PTCA) / stent	Siemens	AXIOM-Artis/2004
Cardiac radiofrequency ablation	GE	Advantx L/C/1994

B. Radiation dosimeters

- **Ionization chamber and electrometer.** Victoreen 4000 M^+ ionization chamber was used for the determination of the table attenuation coefficient, the beam quality half value layer (HVL) and the equipment quality control.
- **Portal film (Verification film).** The non screen ready packed film used for the radiation area verification.
- **Dose Area Product (DAP) meter (Model PTW-Diamentor E).** DAP meter is used to measure the absorbed dose in air (mGy), times the area of the x-ray field (cm^2), on patient skin. The relationship between DAP and exposure-area product (EAP) is essentially a single conversion factor that relates dose to exposure. EAP is expressed in roentgen -cm (R-cm2) and DAP is expressed in gray-cm^2 (Gy-cm^2, usually read in cGy-cm^2).

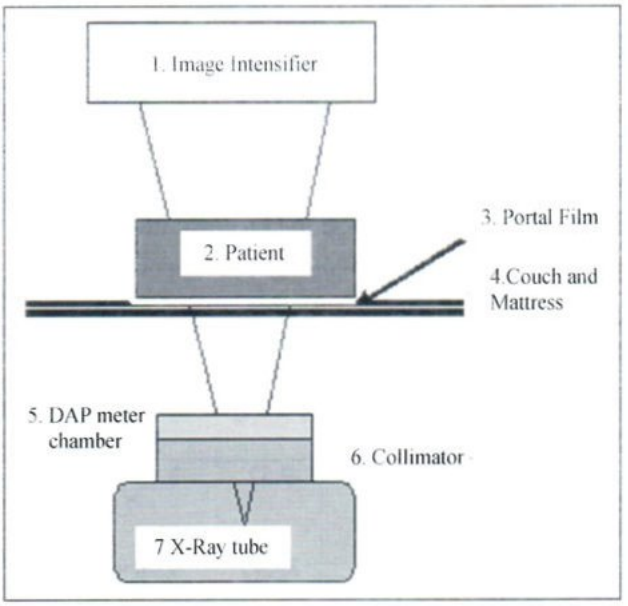

Fig. 1 Setting of the devices for patient skin dose determination

METHODS

The study was carrying out into 5 steps.

1. Quality control of Radiographic/ Fluoroscopic system.

The performance of the Radiographic/ Fluoros- copic system was evaluated with the following studies.[10]

- Dose assessment
- Automatic brightness control test
- Maximum dose rate assessment
- Table attenuation
- Image size assessment
- Half value layer assessment
- Image quality assessment

2. Recorded the patient data collection. The setting of the device for data collection is shown by the followings.

2.1 DAP chamber was placed on the collimator of the x-ray tube.

2.2 Portal film was placed on the couch under the patient around the patient's back at heart portion.

3. Analysis of the data.

3.1 Develop the portal film to determine the radiation area (cm2), calculate the absorbed dose (cGy) from the DAP meter reading (cGy.cm2).

3.2 Determine the absorbed dose in cGy using the data from the DAP meter readout in cGy.cm2 divided by the area from portal film in cm2

3.3 Apply the correction factors from table transmission and DAP Meter calibration and DAP correction factor.

4. Evaluation of the factors affecting the patient skin dose in cardiac catheterization procedure.

5. Evaluation of the correlation between the patient skin dose and the potential related factors such as fluoroscopic time, mAs, kVp, experience of the cardiologists, number of cine frames and patient BMI for cardiac catheterization procedures.

RESULTS

Patient skin dose in cardiac catheterization procedure

The result of patient skin dose for 73 cases are presented in Table 2 and Figure 1. The average patient skin dose from DCA was 9.52 cGy in tube A (Postero-Anterior) and 18.67 cGy in tube B (Lateral), PTCA/stent was 35.95 cGy in tube A and 85.42 cGy in tube B and cardiac radiofrequency ablation was 64.82 cGy for single plane.

Table 2 Patient skin dose in cardiac catheterization procedures.

Procedures	Patient skin dose (cGy)					
	Tube A		Tube B		Single plane	
	Average	Range, Median	Average	Range, Median	Average	Range, Median
DCA (32 cases)	9.52	2.13 - 23.94, 7.75	18.67	2.47 – 77, 16.36	-	
PTCA/ stent (21 cases)	35.95	3.58 - 97.72, 23.86	85.42	20.4 – 451, 53.42	-	
RF ablation (20 cases)			-		64.82	11.9 – 212, 50.78

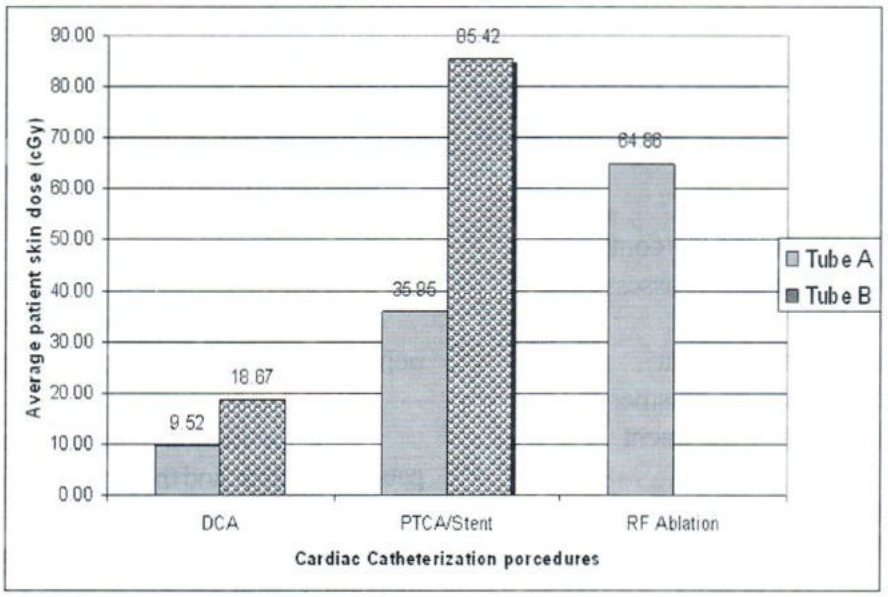

Fig. 2 The average patient skin dose (cGy) in cardiac catheterization procedures.

DAP meter readout in cardiac catheterization procedures

The DAP meter readout (cGy.cm2) for 73 cases is presented in Table 2. The average DAP meter readout from DCA was 861.06 cGy.cm^2 in tube A (Postero-Anterior) and 1,653.59 cGy.cm^2 in tube B (Lateral), PTCA/stent was 3,478.43 cGy.cm^2 in tube A and 7,595.67 cGy.cm^2 in tube B and cardiac radiofrequency ablation was 10,652.70 cGy.cm^2 for single plane

Table 3 DAP meter readout in cardiac catheterization procedures

Procedures	DAP meter readout (cGy.cm^2)					
	Tube A		Tube B		Single plane	
	Average	Range, Median	Average	Range, Median	Average	Range, Median
DCA (32 case)	861.06	171-2287, 843.50	1,653.59	166-7902, 1,510.50		-
PTCA/stent (21 case)	3,478.43	263-9,263, 3023	7,595.67	1,507-36,044, 5,041		-
RF ablation (20 case)			-		10,652.70	1,775-44,702, 7,874

Factors affecting patient skin dose in cardiac catheterization procedures

Factors affecting patient skin dose such as fluoroscopic time, patient body mass index (BMI), the number of cine frames, kVp and mAs are shown in Table 4 and 5 from 32 DCA and 21 PTCA/stent patients.

Table 4 The result of factors affecting patient skin dose in DCA.

Parameter	Tube A		Tube B	
	Average	Range, Median	Average	Range, Median
Fluoroscopic time (min)	2.08	0.50 - 6, 1.50	1.51	0.30 - 7.10, 0.80
Patients Body Mass Index (BMI: kg/m^2)	24.29	15.43 - 38.09, 24.34	24.29	15.43 - 38.09, 24.34
Number of cine frames	495	216 – 1141, 480	480	216 – 1144, 468
kVp for DA and DF	66.50	56.50 - 90.40, 66.50	74.73	64.50 - 101.90, 71.85
mAs for DA and DF	143.82	102.8 - 172.8, 141.80	156.65	109.7 - 179.8, 161.50
kVp for DSA	74.11	62.20 - 99.60, 70	79.28	63.50 - 110.8, 77.95
mAs for DSA	781.37	602.70 - 814.70, 799.80	786.77	649.50-816.60, 801.25

BMI = Body Mass Index **DF** = Diagnostic Fluroscopy
DA = Diagnostic Angiography **DSA** = Diagnostic Systomic Angiography

Table 5 The result of factors affecting patient skin dose in PTCA/stent

Parameter	Tube A		Tube B	
	Average	Range, Median	Average	Range, Median
Fluoroscopic time (min)	7.76	0.80 - 22.50, 6.60	13.64	0.70 - 61.50, 5.70
Patients Body Mass Index (BMI: kg/m^2)	24.42	18.82 - 30.85,23.94	24.42	18.82 - 30.85,23.94
Number of cine frames	941	334 – 1927, 836	936	336 – 1854, 836
kVp for DA and DF	69.15	60.70 - 87.70, 68.00	76.83	67.60 - 92.90, 76.70
mAs for DA and DF	160.85	122.50 - 180.90, 162.70	165.86	141.40 - 182.10, 170
kVp for DSA	72.69	64 - 95.90, 69.50	80.58	67.40-92.10, 81.50
mAs for DSA	774.95	549 – 845.30, 799	801.70	718.70 - 820, 803

The results of the study shows as the data in Table 6 performed on 20 patients of cardiac radiofrequency ablation, show factors affecting patient skin dose such as fluoroscopic time, patient body mass index (BMI), kVp and mAs.

Table 6 The result of Factors affecting patient skin dose in cardiac radiofrequency ablation

Parameter	Cardiac radiofrequency ablation Single plane	
	Average	Range, Median
Fluoroscopic time (min)	24.64	7.00 - 96.70, 16.70
Patients Body Mass Index (BMI: kg/m^2)	23.21	18.37 - 29.38, 22.13
kVp for DA and DF	76.60	75.00 - 92.00, 75.00
mAs for DA and DF	2.58	1.00 - 6.20, 3.00

Table 7 Experience of the cardiologists in cardiac catheterization procedures

Procedures	Experience of the cardiologists (Years)	
	Average	Range, Median
DCA	11	8-14, 13
PTCA/stent	10	8-14, 9
RF ablation	7	5-9, 7

DISCUSSION

The average patient skin dose and its affecting factors were carefully studied in cardiac catheterization procedures during the year 2004-2006 at King Chulalongkorn Memmorial Hospital. Among 73 patients who underwent cardiac catheterization procedures there are 32 cases of diagnostic cardiac angiography (DCA), 21 cases of cardiac intervention and 20 cases of cardiac radiofrequency ablation. The average patient skin dose from DCA was 9.52 cGy (range, median, 2.13 - 23.94, 7.75) in tube A (Postero -Anterior) and 18.67 cGy (range, median, 2.47 - 77, 16.36) in tube B (Lateral), PTCA/Stent was 35.95

cGy (range, median, 3.58 - 97.72, 23.86) in tube A and 85.42 cGy (range, median, 20.4 - 451, 53.42) in tube B and cardiac radiofrequency ablation was 64.82 cGy (range, median,11.9 - 212, 50.78) for single plane. Two patients received higher than threshold erythema dose of PTCA/Stent (4.51 Gy) and cardiac radiofrequency ablation (2.12 Gy).

DAP meter readout (cGy.cm2) were recorded for all patients who underwent cardiac catheterization procedures. The average from DCA was 861.06 cGy.cm^2 (range, median, 171-2,287, 843.50) in tube A (Postero-Anterior) and 1,653.59 cGy.cm^2 (range, median, 166-7,902, 1,510.50) in tube B (Lateral), PTCA/stent was 3,478.43 cGy.cm^2 (range, median, 263-9,263, 3,023) in tube A and 7,595.67 cGy.cm^2 (range, median, 1,507-36,044, 5,041) in tube B and cardiac radiofrequency ablation was 10,652.70 cGy.cm^2 (range, median, 1,775-44,702, 7,874) for single plane.

Table 8 The correlation coeficient (r) between the average patient skin dose and factors affecting patient skin dose in cardiac catheterization procedures.

Parameters	The correlation coeficient (r)				
	DCA		PTCA/stent		Cardiac RF ablation
	Tube A	Tube B	Tube A	Tube B	Single plane
Fluoroscopic time (min)	0.30	**0.60**	0.47	**0.83**	**0.90**
Patient Body Mass Index (BMI: kg/m^2)	0.28	0.30	0.04	0.13	0.35
number of cine frames	0.30	0.10	**0.64**	**0.70**	-
kVp for DA and DF	0.20	**0.80**	0.34	0.39	0.14
mAs for DA and DF	**0.60**	0.004	0.008	0.12	0.04
kVp for DSA	**0.65**	**0.80**	0.001	0.34	-
mAs for DSA	0.31	0.50	0.41	0.15	-
Experience of cardiologists	0.32	0.16	0.16	0.15	0.30

DSA = Diagnostic Systomic Angiography
DA = Diagnostic Angiography
DF = Diagnostic Fluroscopy

The results were compared with other studies as shown in Table 9 for the number of patients and DAP meter readouts.

Table 9 Comparison DAP readouts with other studies from cardiac catheterization procedures.

Procedures	Study	Number of Patients	DAP meter readout ($Gy.cm^2$) Average	Range or Maximum	Median
DCA	De Putte, S., 2000	62	60.6	144	56.82
	Clark, A. L., 2000	117	14.2	1.1-11.3	-
	Neofotistou, V., 1998	198	72	27-79	-
	Vano, E., 1995	288	66.5	11.6 – 482	45.75
	This study	**32**	**12.57**	**1.66-79.02**	**9.52**
PTCA/stent	Karambatsakidou et al, 2005	10	35.0	16-115	-
	Bazli et al, 2004	32	111	22.4-477	111
	Delichas, M. G., 2003	47	63	13-122	-
	Zorzetto, M., 1997	31	91.8	-	-
	Padovani, R., 1997	54	102	-	-
	Vano et al, 1995	45	66.8	12.8-345	66.8
	This study	**21**	**55.37**	**2.63-360.44**	**35.93**
RF ablation	McFadden, S. L., 2002	50	123	21-430	-
	Webster, C. M., 2001	23	105	14-341	-
	Neofotistou, V., 1998	21	-	2.9-134	-
	Broadhead, D. A., 1997	81	95	-	-
	This study	**20**	**106.52**	**17.75-447.02**	**78.74**

CONCLUSION

Two patients from PTCA/stent and cardiac radiofrequency ablation procedures received skin dose over threshold level for erythema (2 Gy) of 4.51 Gy (fluoroscopic time 96.70 min: 04/05/06) and 2.12 Gy (fluoroscopic time 61.50 min: 16/04/06) respectively.

Fluoroscopic time is a factor showing high correlation with dose to the patient especially in the cardiac ablation of single plane procedures and in DCA, PTCA/stent on tube B of lateral projection of Bi-plane procedures (Table 8). As DAP meter was recorded dose when the exposure was on, the readouts show the amount at different position on skin as the tube moved most of the time. The calculated dose does not account for single position. Furthermore different beam geometries and output modes of operation had been selected. Therefore, the dose determined was average skin dose rather than the maximum skin dose.

The body mass index of a patient is also weakly related to the risk for high skin dose in the cardiac catheterization procedures of this study. This means that the size of a patient is far less an important predictor of the dose to be delivered than are other factors, such as the complexity of a procedure. A large patient will contribute to the elevation of a high dose delivery during a complicated procedure.

The number of cine frames in this study is poor correlation for DCA but better correlation for PTCA/stent. The number of cine frames has little effects in DCA because of a short time procedure and small number of cine frames, while PTCA/stent took longer time and more number of cine frames during

procedure. One of the important factor affecting the patient skin dose is the use of frame rate, for this study is fixed at 15 frames/sec, which was not influence in this study. Nevertheless, it is necesssary to optimize the patient skin dose from low number of cine frames to avoid radiation induced skin injuries in patients who underwent cardiac catheterization procedures. Nowaday the cine frame is dependent on the cardiologists to manage the procedures.

The kVp for DA and DF was poor correlation with the average patient skin dose for cardiac radiofrequency ablation and PTCA/stent at both tubes. For DCA the correlation was good in tube A but poor correlation in tube B. Tube B is at lateral position therefore the kVp is higher than tube A (PA; Postero Anterior position). The correlation between the average patient skin dose and the kVp for DSA was good in tube B and fair in tube A. In PTCA/ Stent, no correlation in tube A and very poor in tube B, as high kVp was used in tube B for in lateral position. The mAs for DA and DF and DSA was poor correlation with the average patient skin dose for DCA and PTCA/stent. Only tube A in DCA the correlation was good. As the equipment is automatic brightness control system, the quality control (QC) program is nescessory for the fluoroscopic x-ray output measurement. The calibration of the equipment, condition of the x-ray tube and any potential changes of the filtration were evaluated. A low radiation output could mean either the kVp or mAs was too low, it's also optimized the average patient skin dose for cardiac catheterization procedures.

The experience of cardiologists is a major factor in dose management but showing poor correlation with the patient skin dose. Fellows training in diagnostic cardiac procedures could causes a significant increase in patient exposure during fluoroscopy. Exposure can be further reduced by limiting the number of diagnostic procedures performed with, or by cardiology fellows. It would be important to decide if a cardiology fellow or only who will eventually become cardiologist should receive enough practical training.

The average patient skin dose from DAP meter is more significantly. It may be estimated from DAP meter readout but determination of the dose was depended on the procedure, the direction of the tubes and the experience of the cardiologist. The calibration of DAP meter is necessary as the routine quality control.

The patient skin dose is an important factor during the cardiac catheterization procedures. Cardiologists and staff should be aware of several parameters influencing the dose, therefore the record of concerned factors should be conducted. In case of the over exposure leading to the skin injury, the cardiologists should inform the clinician to follow up and proper treatment for such the late effects.

The correlation factors should be posted for the staff awareness such as fluoroscopic time on tube B. DAP meter threshold value as mentioned in this study.

DAP = Dose Area Product

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