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Patient Peak Skin Dose and Dose Area Product from Interventional Cardiology Procedures

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Abstract

Information about the peak skin dose and Dose Area product (DAP) from percutaneous transluminal coronary angioplasty (PTCA) and coronary angiography (CA) was collected from three catheter application rooms. The range of maximum photon energy was 50 - 125 kVp and the fluoroscopy time was 0.6 - 52 seconds. Values of up to 143 Gy·cm² for DAP and 0.752 mGy for cumulative dose (CD) were found in CA procedures. Otherwise the DAP and CD for PTCA were found to be 143 Gy·cm² and 2.287 mGy respectively in 3rd Quartile. The relation between the fluoroscopy time and the DAP is also considered. Objectives: The objective of this study is to obtain information about patient peak skin doses (PSD), dose area product (DAP), Fluoroscopy Time (FT) and Cumulative Dose (CD) from PTCA and CA which is the most predominant with respect to high skin doses in addition to other procedures. The aim of this study is also to assess the radiation dose received by patients undergoing interventional radiology procedures, by identifying the procedures that deliver the highest doses. This study is also helpful to establish the reference dose level for adult patients undergoing interventional procedure, and to provide recommendations on how to reduce dose on selected procedures that have been identified to deliver patient dose values near the ICRP (International Commission on Radiological Protection) threshold values.

Keywords

Interventional Radiology, Patient Dose, Fluoroscopy Time, Peak Skin Dose

1. Introduction

Radiation induced skin effects are deterministic in nature, with a generally accepted threshold dose of 2 Gy [1]

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[2]. Peak skin dose has been implemented as a function of the highest radiation dose at any point in patient to stand for the likelihood and severity of radiation-induced skin injury to the patient [1] [3]. The European Union requires that all new interventional and paediatric fluoroscopic equipment incorporate DAP measurement capability. This technology is often available (frequently as an added-cost option) on interventional equipment sold in the United States. DAP is measured in units of Gy·cm^2 and expresses the total X-ray flux in the beam [4]. Because dose decreases proportionately to the square of the distance from the focal spot, and the area of the irradiated field increases proportionally in the same way, DAP is independent of source-to-skin distance [5]. For almost half a century prior to the 1990s, it was difficult to see reports of skin injuries even for staff [6]. The increase in use of fluoroscopy for complicated interventions, which require long fluoroscopy time coupled with a continued lack of awareness among many interventionists and a lack of dose monitoring or no understanding of dose parameters, has resulted in continued occurrence of skin injuries.

DAP Meter Calibration

The calibration factor has to take into account the differences between the dose area product (DAP) displayed by the transmission chamber placed on the collimator and the DAP of the radiation affecting on the patient [6]. The calibration factor is the ratio between the DAP of the radiation which actually impinges on the patient, and the value displayed by the DAP meter. Place the ionization chamber on top of the mattress. Build something to put 4 cm of PMMA sheets on top of the ionization chamber to avoid backscatter. Maintain fluoroscopy until the system accumulates a DAP around 10 Gy·cm^2. Record the accumulated dose with the reference ionization chamber D_{ref} and the DAP measured by the system.

DAP_i: Initial Dose Area Product, from the X-Ray System before irradiation.

DAP_f: Final Dose Area Product, from the X-Ray System after irradiation,

D_{ref}: Dose reading from the ionization chamber (Barracuda).

Applied the next formula to estimate the calibration factor (f) which is equal 0.81 to 0.88 in this study.

$$f = \frac{D_{ref} \cdot Area}{DAP_f - DAP_i} \tag{1}$$

Quality control for fluoroscopy machines is also assessed including kVp, mA beam quality (Half-Value Layer [HVL]) assessment, image quality evaluation and Patient exposures.

2. Materials and Methods

Four X-ray fluoroscopic machines from HMC (Hamad Medical Corporation) in the state of Qatar (one Cath-Lab in Hamad General Hospital and three in Heart Hospital) performing Interventional Cardiology (IC) procedures were engaged in this study. All machines are manufactured by Siemens with a flat panel detector in a C-arm configuration. Radiation doses for approximately 1132 patients were collected including patients' age, gender, and fluoroscopy time (FT), and total DAP readings. In order to establish reference dose levels (RDLs), the third quartile of value from survey data distribution was calculated. The median values of the distribution were also assessed in order to estimate the variation in values. The RDLs were also compared with the RDLs provided by the European Research program (DIMOND) and other references. Total number of patient, age and total number of procedures during the period from 2007 to 2012 are illustrated in **Figure 1**.

3. Result and Discussion

Radiation doses for 1132 patients were collected include patients age, sex, fluoroscopy time (FT), total DAP reading. The range of kVp used in these procedures was 50 - 125 kVp and the fluoroscopy time 0.18 - 52 minutes. For CA procedures, the Dose Area Product values reached 72.14 Gy·cm^2 and the Cumulative Dose values reached 752 mGy. On the other hand, the DAP for and CD for PTCA procedures were found to be 143 Gy·cm^2 and 2287 mGy respectively. Cumulative Dose (CD) was of the order of 2 Gy, the dose limit for radiation injuries. The relation between the fluoroscopy time and the DAP are also considered. It is noticed that the DAP value for CA in Diamond RLs exceeded the HMC DRLs by almost 20% for 3rd quartile values. DAP and decrease in fluoroscopy time was noticed in HMC for the same procedures as shown in **Table 1**.

However DAP is a poor indicator of onset of deterministic effects. A much better indicator is skin entrance

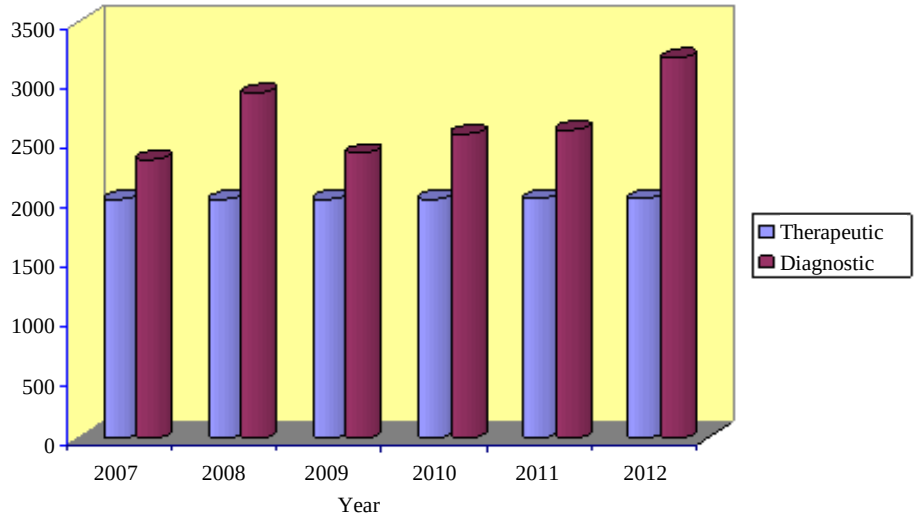

Figure 1. Total number of procedures during the period from 2007 to 2012.

Table 1. Dose parameters for PTCA and CA for HMC and different references levels.

Parameter	HMC Qatar CA		HMC Qatar PTCA		DIMOND 2008 CA	DIMOND 2008 PTCA	I.Mavrikov *et al.* CA	I.Mavrikov *et al.* PTCA
	Median	3rd Quartile	Median	3rd Quartile	3rd Quartile	3rd Quartile	3rd Quartile	3rd Quartile
DAP Gy·cm^2	53.12	72.14	91.9	143.7	57	94	66.3	158
F. Time Min.	2.35	4.67	4.99	8.0	6.0	16	7.7	21.4
CD mGy	379	752	1215	2287	-	-	780	2009
PSD mGy	758	1009	1001	1038	-	-	-	-

dose and, specifically PSD, which is the highest dose in any part of the patient's skin during any interventional procedures and is usually measured in Gy or mGy. Modern X-ray machines provide a quantity that correlates with patient skin dose and PSD, the reference point air kirma (RPAK). RPAK is a measure of the radiation level in a specific point relative to the interventional reference point. This point which is along the central axis of the X-ray beam and 15 cm from the isocenter, is close to the patient's skin surface and is provided by the manufacturer. RPAK was introduced by the International Electrotechnical Commission [7] for standardization purposes and is similar to the reference dose and the cumulative dose used in the past. These three terms can be found in the control units of X-ray machines together with KAP. It does not take into account the scattered radiation and, therefore, is not the actual dose to the patient's skin. For this reason, the latest guidelines of the society of Interventional Radiology (SIR) Safety and Health Committee presented a conversion formula to help operators estimate the PSD from the RPAK shown on the X-ray machine at the end of interventional procedure (8):

$$\mathrm{PSD} = 206 + 0.513 * \mathrm{RPAK}$$

However, it should be noted that this is a broad approximation and not an actual measurement; it cannot be used when RPAK values are below 500 mGy [8]. In order to avoid skin damage, such as transient erythema (2000) msv, the DAP value should not be larger than approximately 520 and 280 Gy·cm^2 for CA and CA plus PTCA which is similar value obtained by Hassan and Karambaskidou [9]. In this study the Dose area product registered only 4.5% from the total number of the patients increase than 100 Gy·cm^2 as shown in **Figure 2**. So this study is under control for the values of DAP compared Karambaskidou.

The relation between cumulative DAP and PSD was investigated for both diagnostic and therapeutic interventions based on all data. These data are presented graphically in **Figure 3**. In this study it found that a strong correlation between the Dose Area product and PSD ($R^2 = 0.87$), conversely, as shown in **Figure 4**, there is a poor

correlation between the total fluoroscopy time (FT) and the PSD (R^2 = 0.39). **Table 2** illustrate the comparing between HMC data for PTCA procedure with different countries results in a work conducted by Tsapaki *et al.* [10], HMC patients have save dose for the average dose less than 100 Gy·cm^2.

For all patients with coronary angiography 78% peak skin doses were well below 1 Gy. This indicated that patients undergoing these diagnostic investigations are unlikely to receive doses sufficient to cause deterministic effects. The distribution of peak skin dose (PSD) for CA procedures is shown in **Figure 5**. The PSD of 1.2% from the total number of patients were more than 2 Gy. If these patients do perform PTCA at a later time, they may likely for early transient skin injury.

Table 2. Countries with hospitals reporting DAP Data specifically on (PTCA) procedures.

Country	No. of Patients with DAP (Gy·cm^2)				DAP < 100% of Patients Exam
	<100	101 - 200	201 - 300	301 - 400	
Qatar (HMC)	740	46	2	0	93.9
Algeria	10	8	3	0	45
Kenya	18	5	1	0	75
Tunisia	14	20	11	0	30
Lebanon	32	11	3	2	67
Syria	33	21	9	4	46
Thailand	9	8	2	0	50
United Arab E	374	81	8	5	80
Pakistan	4	12	14	0	12
Bulgaria	68	19	4	1	72
Croatia	140	12	1	0	92
Greece	25	7	0	0	78
Lithuania	42	0	0	0	100
Slovenia	221	59	9	0	76

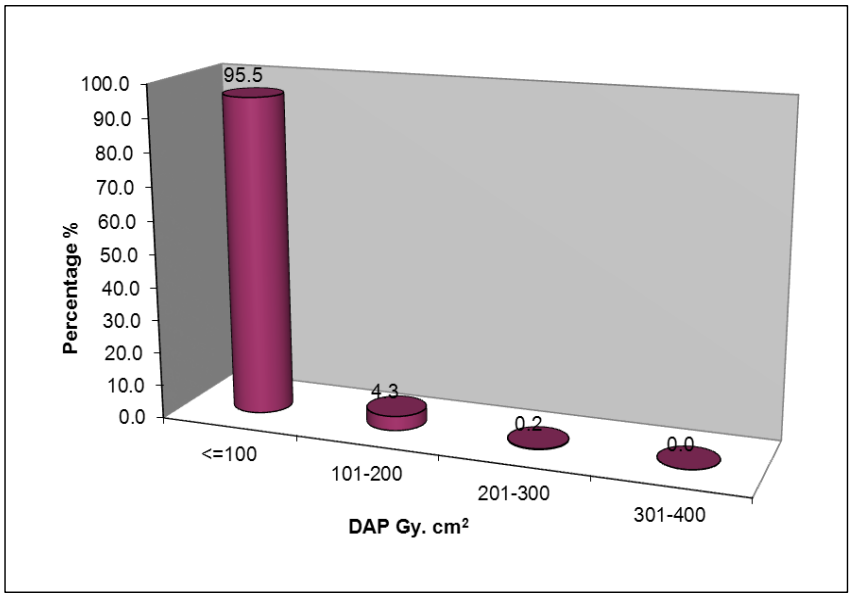

Figure 2. Distribution of the dose area product (DAP) for PTCA procedures.

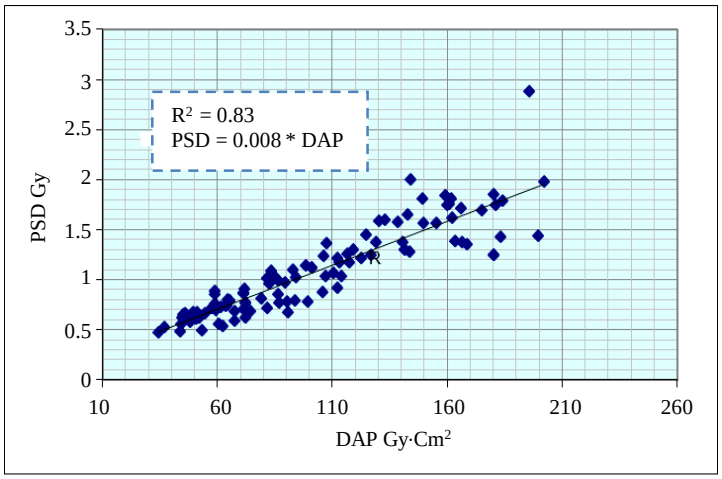

Figure 3. The relation between peak skin dose and dose area product for high skin doses.

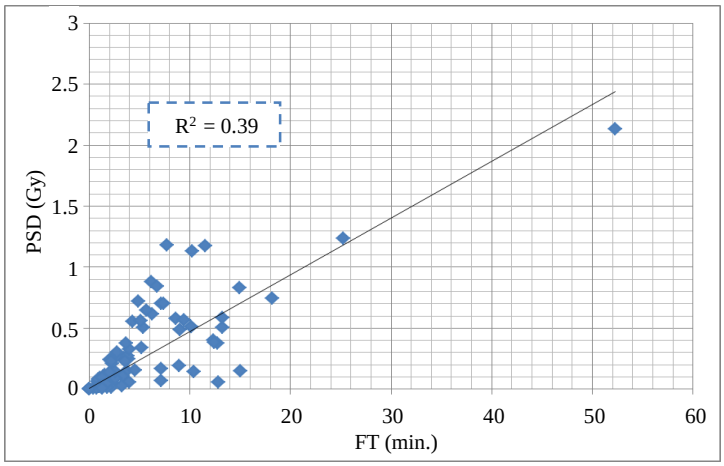

Figure 4. Correlation between fluoroscopy time and peak skin dose.

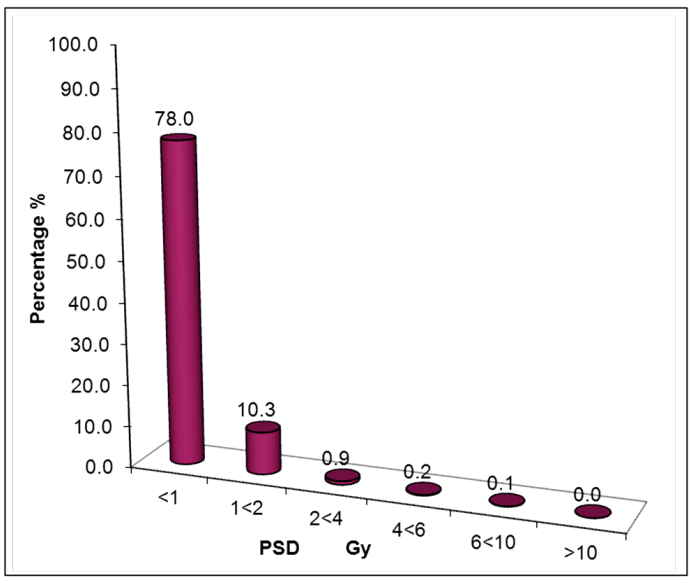

Figure 5. The distribution of peak skin dose (PSD) for CA procedures.

4. Conclusion

In this study, a strong correlation was found between the (DAP) and (PSD). Conversely, there is a poor correlation between the Total Fluoroscopy Time (FT) and the PSD. So, in this study the total DAP can be used as an indicator for PSD. On the other hand, Fluoroscopy Time was found to be a much less reliable indicator of the Peak Skin Dose. The proposed reference levels based on DAP readings are thus about 100 Gy·cm^2, corresponding to PSD of about less than 2 Gy.

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