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Original Article

Evaluation of Maximum Patient Skin Dose Arising from Interventional Cardiology Using Thermoluminescence Dosimeter in Mashhad, Iran

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Abstract

Introduction
The increasing practice of interventional fluoroscopy in diagnosis and treatment of cardiovascular disease has risen attention to improve radiation protection of patients and cardiologists in these relatively high dose techniques. Therefore, nowadays there is an emphasis on the measurement of radiation dose received by patients and cardiologists arising from the relevant procedures.
Materials and Methods
Maximum skin dose of 90 patients in two hospitals in Mashhad have been measured by a grid of 30 thermoluminescent dosimeters (TLDs). The X-ray units were Axiom Artis Siemens in both hospitals which were equipped with integrated dose area product (DAP) meters. The procedures were divided into two groups: diagnostic procedures (angiography and angiography with measurement of left or right ventricle and pulmonary artery) and therapeutic procedures (angioplasty with or without dilatation or stent and angiography with angioplasty). DAP value, fluoro time, and cumulative dose at Interventional Reference Point (CDIRP) were also registered for each procedure.
Results
The mean values of maximum skin dose (MSD) and DAP for diagnostic procedures were 68.51 mGy and 20.96 Gy.cm^2, respectively and for therapeutic procedures 344.18 mGy and 70.94 Gy.cm^2, respectively. A good correlation was found between MSD and DAP (R=0.88) but correlation between MSD and CDIRP was stronger (R=0.90).
Conclusion
MSD values did not exceed the 2000 mGy dose threshold for deterministic effects. The highest MSD obtained for diagnostic procedures was 229.40 mGy and for therapeutic procedures it was 820.50 mGy. The results show that CDIRP can be a fairly good estimate of MSD.

Keywords: Interventional Cardiology; Maximum Skin Dose; TLD.

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1. Introduction

Nowadays we are witnessed to the increasing application of high dose non-invasive procedures such as angiography and angioplasty in the diagnosis and treatment of cardiovascular diseases.

Although these procedures are non-invasive than open heart surgery, including lower risk of death and probably less harmful and a shorter convalescent, the amount of patient radiation dose is high and some reports on radiation skin injuries following cardiac interventions have been reported [1,2]. For complex or successive examinations, patient may suffer from deterministic effects of radiation.

When skin is exposed to high doses, deterministic effects may be more important because their symptoms appear after a certain time following the exposure. According to the report No. 85 and No. 118 of ICRP, the threshold dose for skin deterministic effect by ionizing radiation is 2000 rad [3]. The report also states that patients who receive skin doses higher than 300 rad considered for clinical follow up.

Measurement of patient radiation dose from radiation protection point of view is very important and can reduce the potential disadvantages of such examinations. High radiation dose to the patient may be due to the problems in equipments, cardiologist skill, or expertise of operator.

Today, one of the quantities that can immediately estimate patient skin radiation dose is dose area product (DAP) that is reported by system. This system includes an ionizing chamber which is placed on the includes outlet of the X-ray tube, perpendicular to the beam and displays dose multiplied by the beam area. However, this quantity doesn't give us the actual dose received by the patient, and direct measurement of patient skin radiation dose is necessary for clinical follow up of patients if needed.

Several studies have been carried out in regards to the measurement of patient skin dose and the relationship between this quantity, DAP, fluoroscopy time, number of images, weight of patient, cardiologist's skills. Different and sometimes contradictory results have been reported [4-6].

In this study, maximum skin dose (MSD) of a group of patients who underwent interventional cardiology procedures in two hospitals in Mashhad were measured by TLD. Then, the correlation between this quantity and DAP and fluoro time was estimated. The results were compared with other values reported by other workers in Iran and in other countries.

2. Materials and Methods

In this study, the patient group comprised of 90 adult patients (56 males, 34 females) who underwent cardiac catheterization in Imam Reza and Jvad-Al-Aemmeh hospitals in Mashhad during a period of 3 months (August - November 2012). Imam Reza hospital is a university hospital and Jvad-Al-Aemmeh hospital belongs to the private sector. In each of these two hospitals, 45 patients with Body Mass Index (BMI) between 20 and 30 were chosen for dosimetry by non-random sampling method. Patient demographics are summarized in Table 1. Procedures were divided into two groups: diagnostic procedures (angiography and angiography with measurement of left or right ventricle and pulmonary artery) and therapeutic procedures (angioplasty with or without dilatation or stent and angiography with angioplasty). The diagnostic procedures were performed by experienced cardiologists or medical doctors who had interventional cardiology training, and therapeutic procedures were performed just by experienced cardiologists. The overall number of diagnostic examinations in this study was 56 cases and 28 cases for therapeutic examinations.

Table 1: the patient demographics under cardiac catheterization in two hospitals.

	Diagnostic Procedures		Therapeutic Procedures	
	Mean	Median	Mean	Median
Weight(kg)	68.64	67.00	72.00	75.50
Height(cm)	161.90	160.00	165.14	165.50
Age (year)	57.38	57.00	68.21	48.00
BMI(kg/m^2)	26.07	25.89	26.37	26.42

2.1. X-ray equipments

Imaging system used in both centers were Axiom Artis SIEMENS which have a flat-panel detector and are equipped with a calibrated DAP system. The systems have a variable filtration used in both fluoroscopy and cinegraphy mode that adapts filtration thickness (Al or Cu) according to the thickness of the tissue being irradiated by X-ray, without the operator X-ray involvement. Image field size can be selected e.g.: 16×16, 20×20 or 25×25 cm^2; the systems can also be used in cinemode with images acquired rated between 15-30 frames/s and between 0.5-30 puls/second in fluoromode. The tube voltage and anode current are set by the automatic brightness control.

2.2. Data gathering

Prior to each procedure, the patient information such as weight, height, sex, and age and after the procedure the dosimetry data e.g.: cumulative DAP, fluro time, ciengraphy and fluoroscopy dose, Cumulative Dose at Interventional Reference Point (CDIRP) procedure type, and cardiologist experience were recorded.

2.3. Skin dose measurement of patients

Two dimensional arrays of 30TLDs which provided a grid of 32×40 cm^2 was divided into squares of 8×8 cm covering radiation field was used to measure patient's MSD. The TLDs were placed on a 5-mm thick Perspex plate. The material of Perspex plate is tissue-equivalent and has no interference on diagnostic image quality.

The TLDs used were LiF: Mg, Ti (made by Harshaw) known as TLD – 100. This type of TLD is not radio-opaque and is suitable for dose measurement in diagnostic radiology. All TLDs were calibrated by an ionization chamber (9015model of Radcal,USA)and a diagnostic X-ray machine under manufacturer's protocol at the beam quality that was used in situ. The dosimeters were read by a Harshaw 3500 TLD Reader. Since the X-ray tube was under couch and detector was above the couch, for each procedure the plate with TLDs was placed on the couch under the patient to cover the radiation field.

2.4. Statistical analysis

All calculations were performed by SPSS 11.5 statistical analysis software (SPSS, Chicago). In all statistical analyses, a confidence interval of 95% was applied. Thus, a p-value<0.05 was considered as significant. To check the normality of data distribution, the Kolmogorov-Smirnov test was used and the Pearson's correlation or non-parametric equivalent test was used to assess the correlation between the relevant quantities.

3. Results

In the current study, dosimetry results for diagnostic and therapeutic procedures are shown in Tables 2 and 3.

Overall, mean and median MSD received by patients for diagnostic procedures were 68.51 and 56.85 mGy, respectively and for therapeutic procedures were 344.18 and 267.65mGy. The distribution of MSDs measured by TLDs and DAP for the population of patients for diagnostic and therapeutic procedures are shown in Figures 1 and 2.

Table 2. Dosimetry results for patients who underwent diagnostic procedures in two hospitals.

	Fluoro Time(min)	DAPtotal (Gy cm2)	Dosetotal (mGy)	MSD (mGy)	Cine/Dosetotal (%)	Fluoro/Dosetotal (%)
Max	11.06	60.40	796.00	229.40	87.11	57.17
Min	0.50	4.60	59.30	17.50	32.30	12.89
Mean	2.16	20.96	318.75	68.51	74.17	25.27
Median	1.46	18.40	295.25	56.82	76.81	22.84
SD	1.88	11.26	155.85	38.48	9.12	9.12

Table 3. Dosimetry results for patients who underwent therapeutic procedures in the two hospitals.

	Fluoro Time(min)	DAPtotal (Gy cm2)	Dosetotal (mGy)	MSD mGy)	Cine/ Dosetotal (%)	Fluoro/ Dosetotal (%)
Max	20.34	201.10	3399.00	820.50	73.90	70.07
Min	2.10	13.40	189.00	59.30	29.93	26.10
Mean	9.45	70.94	1102.88	344.18	50.63	49.36
Median	9.04	60.65	909.00	267.65	53.62	46.37
SD	4.97	43.16	718.18	199.24	10.65	10.65

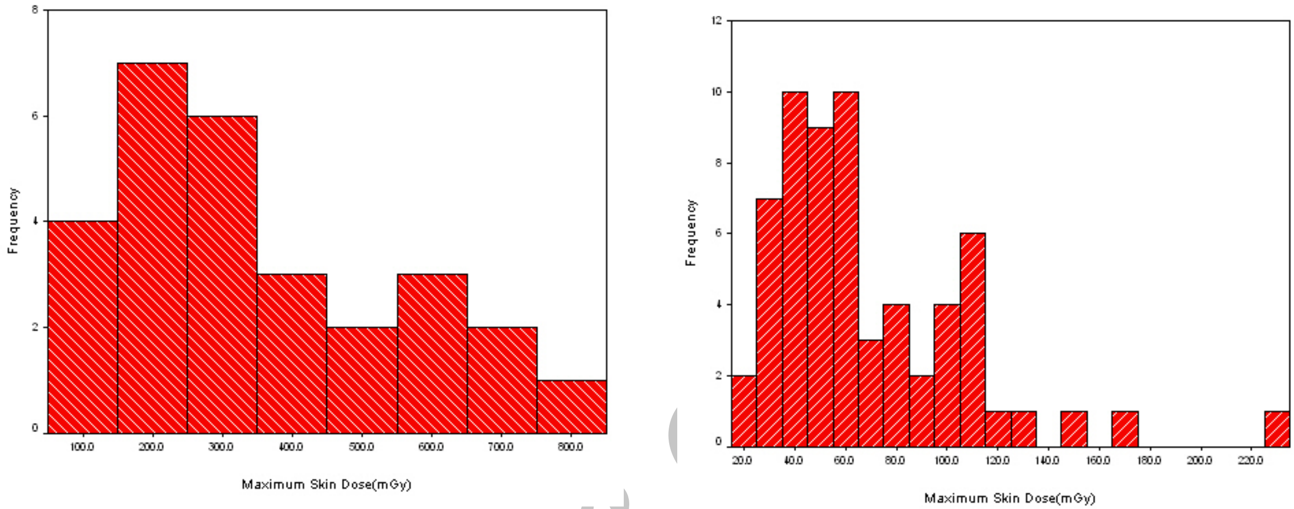

Figure 1: The frequency distribution of the MSDs for the population of patients for diagnostic (right) and therapeutic procedures (left)

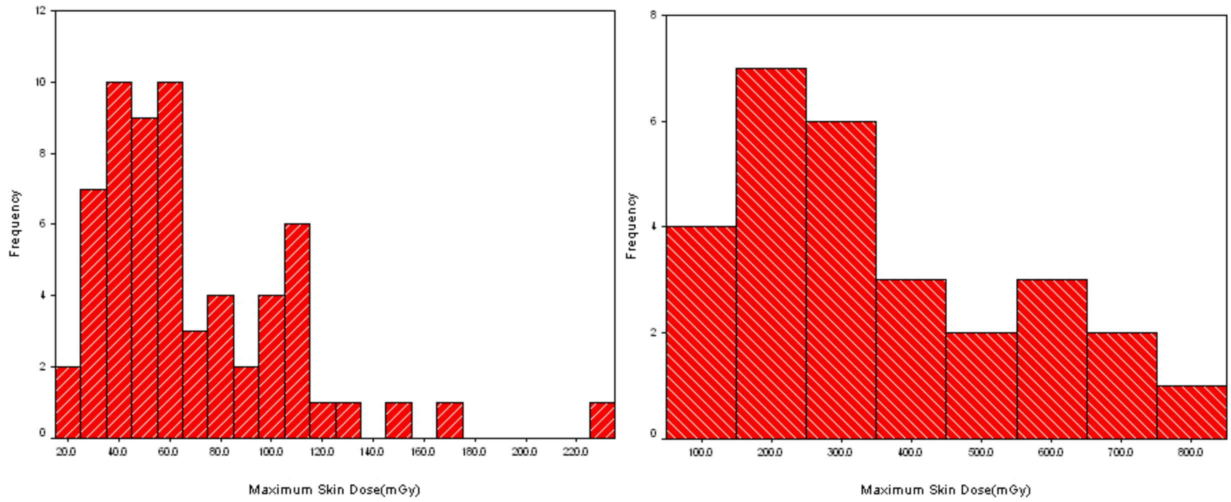

Figure 2. The frequency distribution of the DAPs for the population of patients for diagnostic (right) and therapeutic procedures (left)

3.1. Skin dose distribution of patients

Each view of imaging is determined by a set of two angles per tube: cranial and caudal rotations in the sagittal plane and left anterior oblique (LAO) and right anterior oblique (RAO) rotations in the transverse plane.

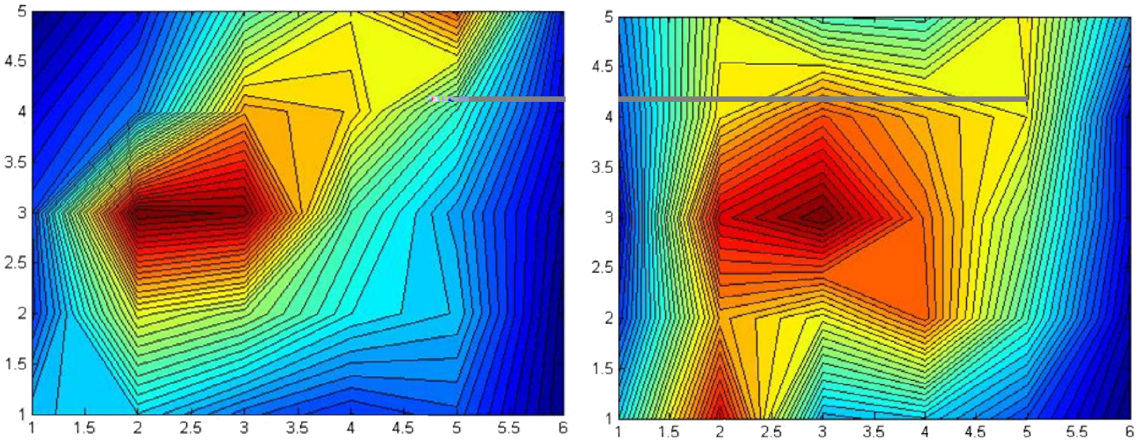

Figure 3. Skin dose distribution of patients who underwent diagnostic (right) and therapeutic procedures (left).

The dose contour of patient's skin was obtained by MATLAB_6.5 software (Figure 3). Areas with the highest dose are shown by red and areas with the lowest dose are shown with blue. As it can be seen, the highest skin dose is related toLAO angles. Due to the fact that patients' chest is thicker in the lateral than in the anteroposterior dimension, an increase in exposure can be observed.

3.2. Statistical correlations between MSD and other dosimetric quantities

The correlation between MSD and cumulative DAP for all patients who underwent cardiac intervention in both centers was investigated. Spearman's correlation test was used. There was a good correlation with R=0.88 correlation coefficient and p=0.00 significant level.

We can predict direct relationship between MSD and fluoro time. Since the DAP system is not installed in majority of working systems, finding the relationship between two quantities as an estimator for doctor and patient dose can be very useful. A Spearman's correlation coefficient was found, R=0.85 with p-value=0.00, which shows a correlation between MSD and DAP, a relatively good correlation between these two quantities.

One of the important quantities that are measured by Axiom Artis SIEMENS system, is CDIRP and this quantity is given as an estimate of the dose received by the patient's skin. Spearman's correlation coefficient was found to be equal to 0.90 with p-value=0.00.

4. Discussion

In this study, MSD of a group of patient who underwent some cardiac interventions was measured by TLD in two hospitals in Mashhad Then, the correlation between this quantity and DAP and fluoro time as online indicators of dose were evaluated.

Mean MSDs for diagnostic and therapeutic procedures were 68.51 mGy and 344.18 mGy, respectively. The average fluoro time for diagnostic procedures were 2 minutes and 16 seconds, 4.3 times more than fluoro time in therapeutic procedures (9 minutes and 45 seconds). Dosimetry results showed no MSD higher than skin dose threshold. The highest MSD for diagnostic procedures was 229.40 mGy and for therapeutic procedures 820.50 mGy. Tables 4 and 5 provide possibility of comparing the dosimetry results obtained in this study with a number of other studies carried out in recent years in other countries. It is evident that the average DAP for diagnostic and therapeutic examinations in this study compared with other studies, with the exception of Nada study in Sudan, is in lower [7]. Moreover, fluoro time in this study is the lowest compared with studies performed elsewhere. Despite little information available in literature in regards to MSD, mean MSD obtained in this study is the lowest. Comparison of our results with the corresponding values reported by Mesbahi et al. in Tabriz, are evident patients studied for both diagnostic and therapeutic procedures in Mashhad received lower doses[8].

Table 4. Dosimetry results for diagnostic procedures reported by other researchers compared with this study.

Reference	n.cases	Mean DAP(Gycm2)	Median DAP(Gycm2)	Mean Fluoro Time(min)	Mean MSD(Gy)	Median MSD(Gy)
Bogaert et al. [9]	200	55.7	43.7	…	0.31	0.2
Giordano et al. [10]	8	41.55	39.19	5.26	0.16	0.09
Samara et al. [11]	311	87	…	14	…	…
Nada et al. [7]	179	20	17.9	5.2	…	…
Worawut et al. [12]	241	45.2	37.4	5.7	…	…
Bor et al. [13]	194	49.1	…	4.3	…	…
Mesbahi et al. [8]	203	23.7	…	5.8	…	…
Pantos et al. [14]	9100	39.9	41.7	4.7	0.35	…
This study	62	20.96	18.4	2.16	0.07	0.05

Table 5. Dosimetry results for therapeutic procedures reported by other researchers compared with this study.

Reference	No. of Cases	Mean DAP(Gycm2)	Median DAP(Gycm2)	Mean Fluoro Time(min)	Mean MSD(Gy)	Median MSD(Gy)
Bogaert et al. [9]	118	81.5	65.4	…	0.69	0.46
Giordano et al. [10]	16	149.15	95.03	21.24	0.96	0.49
Samara et al. [11]	119	91	…	32	…	…
Koichi et al. [4]	172	148.6	…	37.4	…	1.45
Nada et al. [7]	86	56.5	50.3	17.6	…	…
Worawut et al. [12]	198	97.8	80.5	13.3	…	…
Bor et al. [13]	91	106.9	…	14.25	…	…
Mesbahi et al. [8]	33	91.5	…	11.3	…	…
This study	28	70.94	60.65	9.45	0.34	0.27

The mean fluoro dose and cine dose to the total dose received by patients are shown separately in two pie charts (Figure 4). It can be seen that on average, cinegraphiec dose is approximately 3 times the dose received by patients due to fluoroscopy in diagnostic procedures.

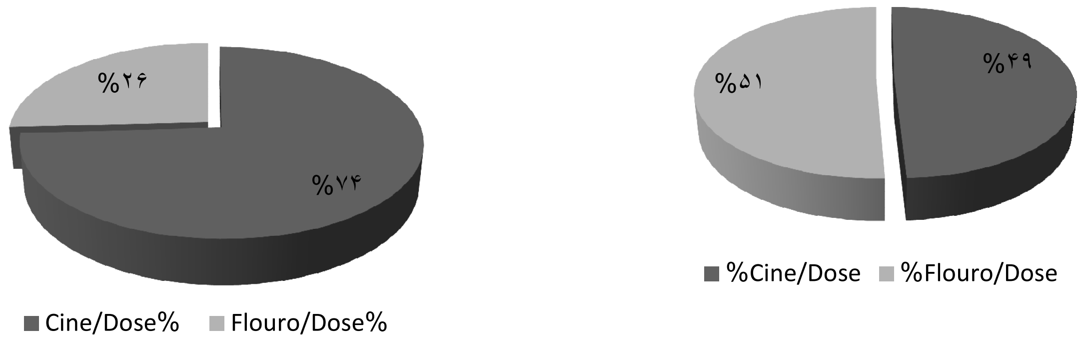

Figure 4. The mean contribution of Flouro and cine dose to total dose for diagnostic (left) and therapeutic (right) procedures.

The correlation coefficient between MSD and DAP was R=0.88 (p=0.00) using spearman's correlation compared with the study done by Blair et al. that measured MSD by radio chromic films for 20 patients who underwent angiography and angioplasty (R=0.76) which shows a stronger correlation [15].

Statistical correlation between MSD and DAP for two types of procedures separately, were analyzed using Pearson's correlation and the correlation coefficients were found to be equal to 0.79 and 0.69 for diagnostic and therapeutic procedures, respectively, which shows stronger correlation between two quantities in diagnostic procedures than therapeutic procedures. This is in contrary to the results of Giordano et al. Who showed stronger correlation between two quantities in therapeutic procedures than diagnostic procedures [10].

Statistical correlation between MSD and fluoro time using Spearman's correlation for two types of procedures was found to be equal to 0.85 with a significant level of 0.00. This correlation for diagnostic procedures was found to be equal to 0.66 (p=0.00) and for therapeutic procedures, because of the greater part of dose received by the patient due to fluoroscopy, Pearson's correlation coefficient was found to be equal to 0.79 (p=0.00) that was similar to the results of Giordano et al. (R=0.79, p=0.00).

For CDIRP, that is a new dosimetric quantity provided as an estimate of patient MSD, we found a stronger Pearson's correlation between MSD and CDIRP in diagnostic procedures (R=0.82, p=0.00) than therapeutic procedures (R=0.68, p=0.00). The correlation coefficient was found to be equal to 0.90 (p=0.00) for both diagnostic and therapeutic procedures using Spearman's test. In general, we can conclude that this quantity provides approximately a good estimate of patient skin dose and may be more useful than DAP or fluoro time and this result is in agreement with Zontar et al. result [16].

We did not find a significant correlation (p=0.2) between DAP, BMI or weight of patients (0.09).

5. Conclusion

MSD values didn't exceed the 2000 mGy dose for individual patient in the studied group. The highest MSD for diagnostic procedures was 229.40 mGy and for therapeutic procedures it was 820.50 mGy. The results show that CDIRP is a fairly good estimator of MSD in this procedure.

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