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Assessment of Patient Radiation Dose in Interventional Procedures at Shahid Madani Heart Center in Khorramabad, Iran

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ABSTRACT

Introduction: Coronary angiography is the most common angiographic procedure for diagnosis and treatment of the heart diseases. Herein, we aimed to evaluate the entrance surface dose (ESD), dose area product (DAP), as well as cancer risk in interventional cardiology procedures.
Materials and Methods: This study was conducted during July-December 2015 at Shahid Madani Heart Center in Khorramabad, Iran. A total of 225 adult patients including 122 females and 103 males regardless of the risk factors for coronary diseases were participated. Of them, 199 and 26 patients underwent diagnostic coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA), respectively. Each patient underwent CA or PTCA separately. All the procedures were carried out using Siemens angiography system with the pulsed fluoroscopy of 10-30 pulses/s and cine frame rate of 15 frames/s. DAP, ESD, fluoroscopy time (FT), as well as the number of sequences and frames per sequence were collected for each 199 CA and 26 PTCA procedures.
Results: The median values of DAP were 19.77±14.88 and 57.11±33.36 Gy.cm^2 in CA and PTCA, respectively. In addition, the median values of ESD were 323.12±245.39 and 1145.22±594.42 mGy in CA and PTCA, respectively. FTs were 114.59±74.33 s in CA and 424.15±292.93 s in PTCA.
Conclusion: The average patient dose and cancer risk estimates in both CA and PTCA were consistent with the reference levels. However, in agreement with other interventional procedures, dose levels in the interventional cardiology are influenced by staff and clinical protocols, as well as the type of equipment.

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Introduction

In recent years, interventional cardiology has been one of the most standard procedures in both diagnosis and treatment of heart diseases [1]. However, increased number of coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA) examinations expose patients to significant doses of ionizing radiation [2]. On the other hand, to assess the deterministic effects, and in some cases, cancer risk attributable to CA and PTCA procedures, a wide range of studies were undertaken across the world [3-6]. In this regard, definition of the radiation dose indices such as dose area product (DAP) and entrance surface dose (ESD) in patients is of great significance. It is demonstrated that DAP measurement for the effective dose calculation and thermoluminescent dosimetry (TLD) for the ESD estimates are found to be the most reliable methods for patient radiation dosimetry [3].

Assessment of skin dose of patients undergoing CA and PTCA was performed by Tavakoli et al. [4]. Their results showed that respectively 85% and 78% of cases undergoing CA and PTCA received maximum skin dose of lower than 25 cGy, well below the threshold of 2 Gy, suggesting transient erythema. Stratis et al. measured the DAP values for CA and PTCA to be 19.96 and 40.17 Gy.cm2, respectively. They found a strong correlation between DAP and fluoroscopy time (FT), the number of frames per sequence, and hence the cine recording time [5]. Patients' maximum skin dose using GAFChromic films was evaluated in the literature [6]. The skin doses and DAPs of 325 patients were also measured using alternative dosimetric techniques for different cardiological examinations [7].

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In this study, we reported strong correlations between DAP results and the entrance skin doses calculated by air kerma (AK) measurements and direct DAP readings. Radiation exposure with the radial approach was compared with that in femoral approach revealing that the radial approach was associated with significantly higher DAPs and FTs [8]. However, some researchers reported conflicting results [9], and the International Commission on Radiological Protection (ICRP) recommended the risk of fatal carcinogenesis attributable to exposure to total-body irradiation [10].

Therefore, we conducted this study to assess ESD and DAP and expound the associated cancer risks resulting from ionization radiation during both CA and PTCA examinations.

Materials and Methods

This study was conducted at Shahid Madani Heart Center in Khorramabad, Iran, during July-December 2015. A total of 225 adult patients including 122 females and 103 males regardless of the risk factors related to coronary diseases were recruited. A total of 199 and 26 patients underwent CA and PTCA, respectively, with stenting in one or more coronary stenosis. Each patient underwent CA or PTCA separately. In all the cases, the radiological device was Siemens AG 2004 (AXIOM Artis, Version VB 11, Germany), which was calibrated four months before the study. This unit is capable of performing low- and standard-dose fluoroscopy with 15 pulses per second and an image acquisition rate of 15 or 30 frames per second; the total filtration was 0.017 cm Cu.

The angiographic unit was equipped with a patient-dose measuring system placed in front of the X-ray tube (Diamentor M4 KDK, PTW Freiburg GmbH, Germany). This meter consists of a flat ionization chamber measuring DAP in Gy.cm^2 and a ionization chamber calibrated to measure the ESD in mGy at the center of the radiation field and at 70 cm from the focus of the X-ray tube. For each examination, we investigated the correlation between the following parameters: number of frames and DAP_{cine}, FT and DAP_{fluoro}, number of frames and ESD_{cine}, as well as FT and ESD_{fluoro} separately for the CA and PTCA examinations.

In all the subjects, we analyzed mean values, standard deviations, medians, minimum and maximum DAP_s, ESD_s, and the above-mentioned parameters for CA and PTCA in both fluoroscopy and cine angiography. Statistical analysis was carried out using SPSS, version 21.

Results

Table 1 exhibits the mean values of DAP and ESD for CA and PTCA for men and women, in both fluoroscopy and cine angiography. In CA, 55.8% of patients were women, while in PTCA, 57.7% of the cases were men.

Table 1. Mean value of DAP and ESD in fluoroscopy and cine angiography in men and women during CA and PTCA procedures

	Sex	No	%	DAP_{fluoro} (Gy.cm^2)	DAP_{cine}(Gy.cm^2)	Fluoro ESD (mGy)	Cine ESD (mGy)
CA	Women	111	55.8	9.9325	7.0695	153.9306	117.6471
	Men	88	44.2	13.4766	9.8116	217.7830	170.3423
PTCA	Women	11	42.3	38.6385	19.9418	390.15660	203.49901
	Men	15	57.7	35.7172	20.3326	704.2933	375.2960

Table 2. Statistical parameters of dose distribution, time, kV, and mAs, in terms of min, max, mean, and SD during CA and PTCA procedures

CA	Min	Max	Mean	SD
kV	70.00	93.83	74.30	4.75
mAs	1.13	5.92	4.10	1.11
DAPCine (Gy.cm2)	0.84	39.72	8.28	6.23
ESDcine (mGy)	12.78	715.80	140.94	107.80
Fluoro Time(s)	36.00	510.00	114.59	74.33
DAPFluoro (Gy.cm2)	1.36	59.76	11.49	8.78
ESD_{Fluoro} (mGy)	18.70	977.00	182.16	138.85
Cine frames	60.00	765.00	299.84	166.35
PTCA				
kV	70.25	98.50	79.36	7.11
mAs	2.95	6.19	4.89	0.82
DAP_{Cine} (Gy.cm^2)	5.28	44.46	20.16	10.71
ESD_{cine} (mGy)	164.88	836.38	393.09	201.48
Fluoro Time (s)	114.00	1554.00	424.15	292.93
DAP_{Fluoro} (Gy.cm^2)	12.17	98.30	36.95	23.81
ESD_{Fluoro} (mGy)	198.40	1892.00	752.11	429.19
Cine frames	345	1215	672.69	252.31

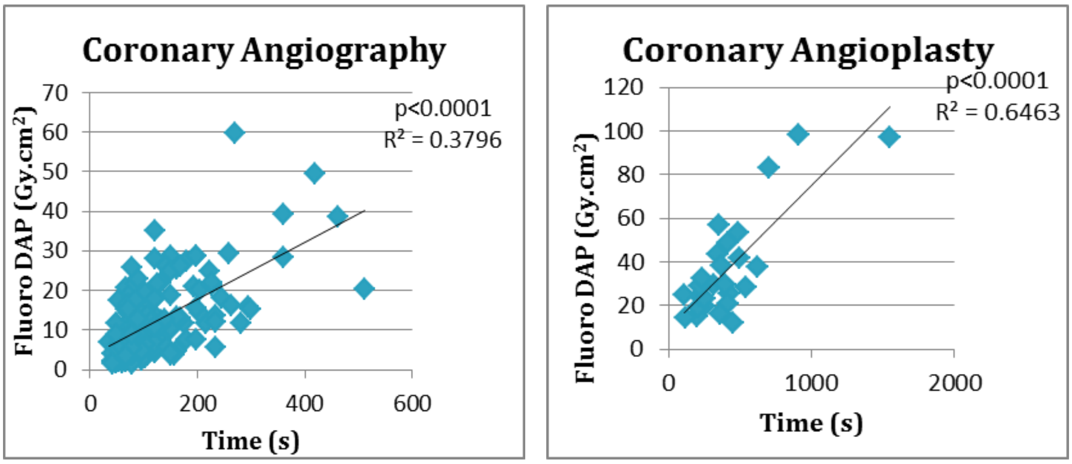

Figure 1. Correlation between DAP_{fluoro} and fluoroscopy time for both CA and PTCA procedures

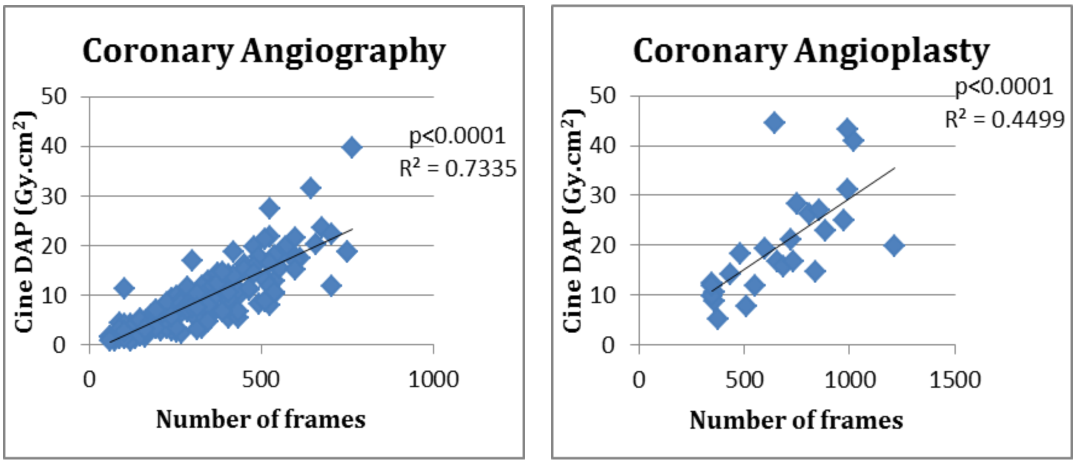

Figure 2. Correlation between DAP_{cine} and number of frames for both CA and PTCA procedures

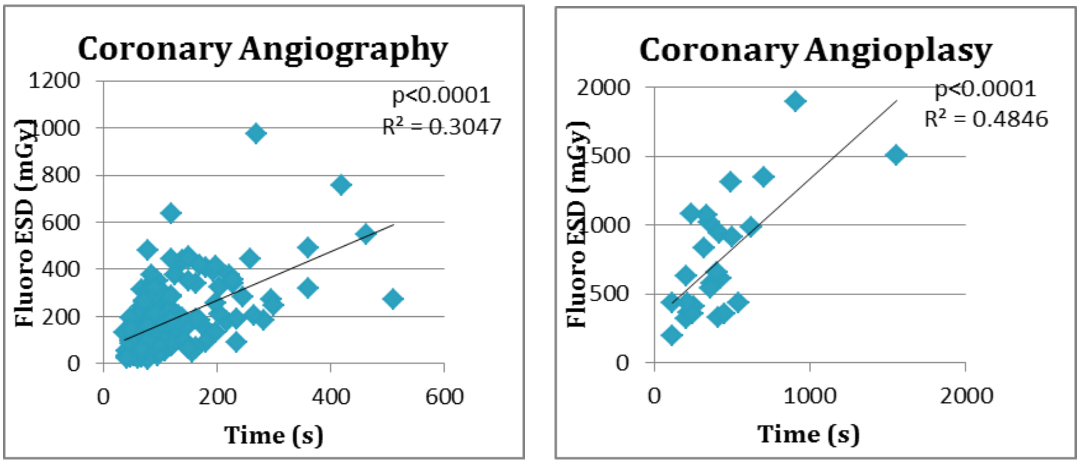

Figure 3. Correlation between ESD_{fluoro} and fluoroscopy time for both CA and PTCA procedures

Table 2 shows the dose indices and exposure parameters calculated regardless of gender in order to give exact information about CA and PTCA procedures.

The correlation between DAP_{fluoro} and fluoroscopy time, DAP_{cine} and number of frames, ESD_{fluoro} and fluoroscopy time, as well as ESD_{cine} and number of frames, which were investigated in both CA and PTCA procedures, is shown in figures 1, 2, 3, and 4.

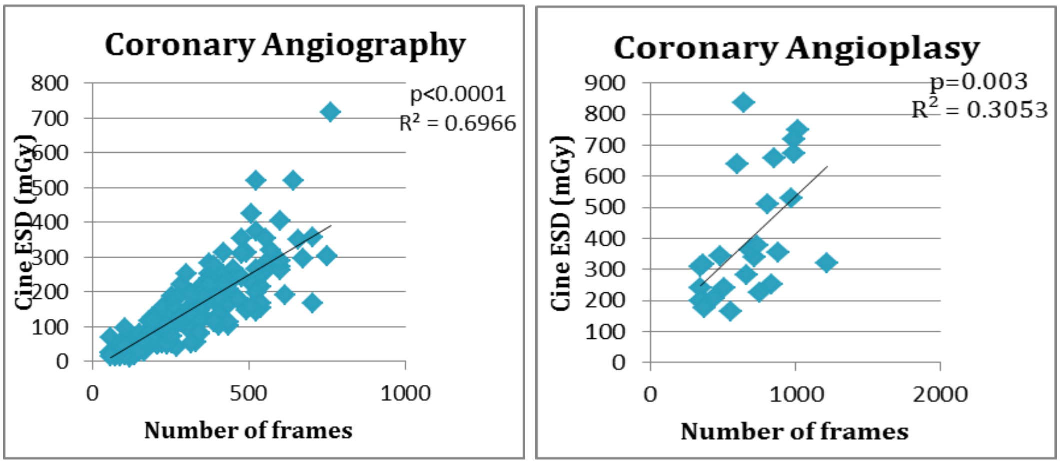

Figure 4. Correlation between ESD_{cine} and number of frames for both CA and PTCA procedures

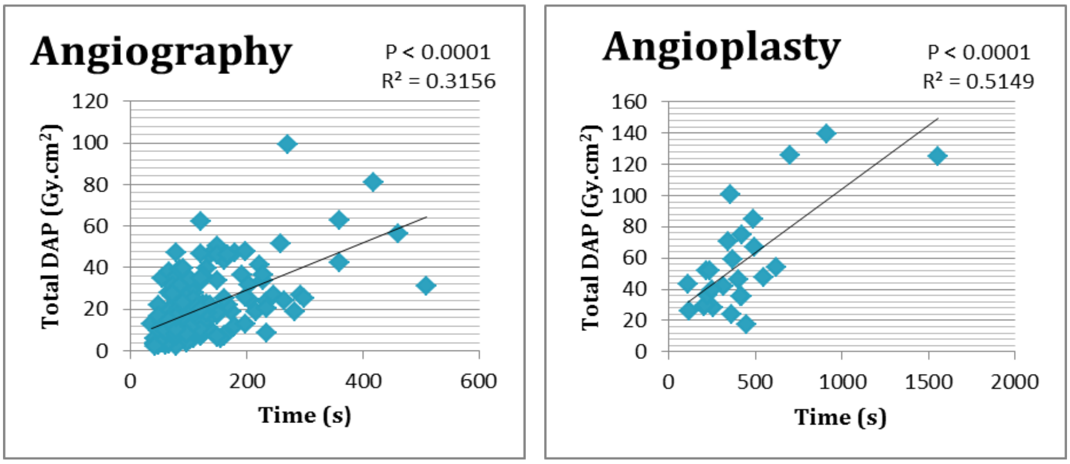

Figure 5. Correlation between DAP_{Total} and time for both CA and PTCA procedures.

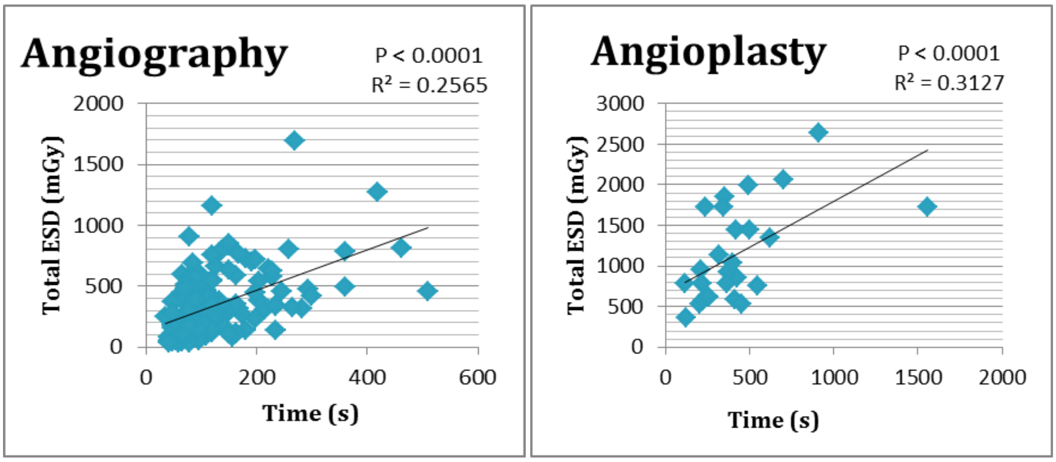

Figure 6. Correlation between ESD_{Total} and time for both CA and PTCA procedures

The correlation between total DAP and time for both CA and PTCA procedures were shown in Figure 5.

Furthermore, in Figure 6 correlations between total ESD and time for both CA and PTCA procedures is observed.

Finally, correlation of total ESD with total DAP for both CA and PTCA procedures are indicated in Figure 7.

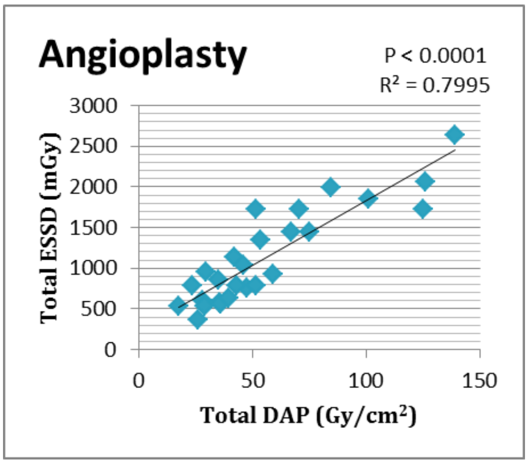

Figure 7. Correlation between total ESD with total DAP for both CA and PTCA procedures

Discussion

In recent years, the increasing frequency of interventional cardiology procedures in Khorramabad city, Iran, has raised the radiation exposure of the population. Although beneficial results of CA and PTCA procedures in diagnosis of cardiovascular diseases are conspicuous, these examinations are characterized by prolonged FTs. Therefore, evaluation of dose indices in patients undergoing interventional procedures is necessary to assess its deterministic and stochastic effects.

In Table 1, mean values of DAP and ESD in CA and PTCA for men and women in both fluoroscopy and cine angiography are presented. In all cases of CA procedure, patient dose in men was higher than that of women. Similarly, in PTCA, except for DAP_{fluoro}, patient dose in men was higher than that of women; some factors such as men's body size and type of procedure may explain this difference. However, further studies are necessary to illustrate these differences in dose values.

The values of dose distribution and device parameters regardless of gender also are shown in Table 2. As can be noted, the values of DAP_{Cine}, ESD_{cine}, DAP_{Fluoro}, ESD_{fluoro}, and cine frames were higher in PTCA than those in CA procedure; similar findings were reported by other researchers [4]. It seems that the main reason for these differences is the prolonged FT that was approximately four times higher in PTCA than CA procedure. However, due to the type of anatomical disorders and procedures these differences are unavoidable.

As presented in Figure 1 for both CA (left) and PTCA (right) procedures, there was a strong correlation between DAP_{fluoro} and FT values, as well as between DAP_{cine} and number of frames for both CA (left) and PTCA (right) procedures (Figure 2). Stratis et al. revealed a strong correlation between DAP and FT, the number of frames per sequence, and hence the cine recording time [5].

Figures 3 and 4 illustrate the comparison between ESD_{fluoro} and FT, as well as ESD_{cine} and the number of frames that were investigated in both CA and PTCA. Figure 3 presents a strong correlation between FT and dose indices in both procedures. Figure 4 demonstrates that the results were the same for both procedures. These results are in agreement with those reported by previous studies [4-6]. In addition, we calculated the correlation between DAP_{Total} and time for both CA and PTCA procedures (Figure 5), the results of which correspond to those of former studies [11]. Furthermore, as seen in Figure 6, there are some variations in ESD_{Total} values, for example in several cases ESD_{total} was very high exceeding the reference values.

In one of 199 CA cases (0.5%) and 7 of 26 PTCAs cases (27%), the ESD_{total} reached the threshold value of 2 Gy for deterministic effects. However, in three cases, the ESD_{total} exceeded the threshold dose value. Therefore, this procedure is not mandatory to keep the radiation exposure in line with the established radiation protection principles. Finally, as exhibited in Figure 7, there was a strong correlation between ESDtotal and DAPtotal for both CA (left) and PTCA (right) procedures. The United Nations Scientific Committee on Effects of Atomic radiation (UNSCEAR) proposed the range of effective doses per procedure for CA and PTCA to be 3.1-15.8 mSv and 5.4-14.1 mSv, respectively [12]. Entrance skin dose observed in CA was within a range of 0.021-1.7 Gy, which was less than the threshold value of 2 Gy, at which erythema could occur. The values in PTCA were within the range of 0.36-2.73 Gy, which were higher than the threshold values of 2 Gy. These results are congruent with those reported by other studies [13-15]. More prolonged duration in angioplasty than angiography can be the main reason for the increasing effective dose. Our findings revealed that the mean received effective dose by patients was 3.61 mSv for CA and 10.45 mSv for PTCA. The estimated effective dose and cancer risk were calculated with the formula DAP × 0.183 mSv/Gy.cm2, validated by National Radiological Protection Board (NRPB) for CA and PTCA examinations [10].

The fatal cancer risks of 0.035% and 0.013% were estimated for CA and PTCA, respectively. Mean values of effective dose are inconsistent with those ranged by ICRP [10]. In the diagnostic CA, all the parameters, including DAP_{total}, FT, and number of frames (except ESD), were in agreement with those values reported by the literature (12-17). However, despite the impact of some factors including technical problems, anatomic and coronary abnormalities, experience of interventional cardiologists, and even type and quality of catheters, standard deviation values are close to mean values of ESD_{total} and DAP_{total} for both CA and PTCA procedures. These results indicated that both cardiologists and technologists have good experience in interventional procedures.

Conclusion

Our results regarding effective dose and cancer risk were in agreement with the reference levels in interventional cardiology. In line with other interventional procedures, dose levels in the interventional cardiology are influenced by staff, the applied clinical protocol, as well as the type of equipment. Thus, training cardiologists, awareness regarding equipment performance, and optimization of procedures are necessary. In future publications we are going to verify these results with those of TLD.

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