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Evaluation of Correlation between DAP (Dose-Area Product) Values and Cardiologist Dose during Coronary Angiography Using Monte Carlo Simulation

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ABSTRACT

Introduction: The present study investigated the correlations between the patient's dose-area product (DAP) values and cardiologist's dose using Monte Carlo simulation. During angiography procedures, patients are exposed to the primary beam; however, the cardiologist is irradiated by the scattered radiation arising from the table and the surrounding equipment. Accordingly, the cardiologist's dose is directly related to the patient's dose.

Material and Methods: This study investigated 25 cardiac angiography procedures. In each procedure, the DAP readings and the cardiologist dose as measured using an electronic personal dosimeter placed over the apron were recorded. Moreover, the DAP values and dose received by the cardiologist in the chest region were calculated using the Monte Carlo N-Particle extended code. For the validation of the simulated spectrum, dosimetric measurements were made using a Farmer ionization chamber and a phantom.

Results: The data obtained from 18 simulations showed that there was a strong linear relationship (R^2=0.71) between the two variables of cardiologist's dose and patient's DAP. Likewise, the obtained results of dosimetry conducted on the patients in 25 cardiac angiography procedures revealed that there was a strong relationship (R^2=0.78) between the two variables.

Conclusion: The reported correlation rates show the appropriateness of the physician radiation exposure to total patient's DAP. With respect to the strong correlation coefficient obtained from the simulation method, it is recommended that this method should be verified by dosimetry. The findings of this study showed a linear relationship between the cardiologist's dose and the total dose of the patient.

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Introduction

Medical exposure is the largest source of ionizing radiation for the human body since approximately 3.6 billion medical radiation procedures are annually performed across the world [1]. On the other hand, coronary artery diseases are the leading cause of cardiovascular death throughout the world in the civilized population and account for about 33.7% of the world's mortalities [2]. The interventional procedures and fluoroscopy-guided procedures play an important role in the diagnosis and treatment of these diseases. Among these procedures, the most usable one is the cardiac interventional procedure which has allocated about 12% of all radiological examinations and accounts for 48% of their total collective dose [3,4].

In cardiac interventional procedures, radiation doses to patients are relatively high, compared to conventional radiographic procedures; this is due to the high complication of these procedures and long duration of fluoroscopy [5,6]. Accordingly, the mean dose received by the patient is equal to 10-50 mSv per procedure [7]. These high levels of patient's dose lead to high levels of operator's received dose that are under the irradiation of scattering beam arising from the patient's body [5]. The average operator's dose in each coronary angiography (CA) procedure is equal to 0.4-38 μSv [7].

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In another report, the mean effective dose of cardiologist per procedure is about 2.7 μSv (range: 0.3-14.3 μSv) for CA and 6.4 μSv (range: 1.3-27.5 μSv) for percutaneous transluminal coronary angioplasty (PTCA) [8]. Therefore, in the angiography and fluoroscopy department, due to high dose levels, requirement for the cardiologist's presence near the patient during the procedure, and long time spent for the fluoroscopy, the cardiologist receives a high level of dose. Consequently, careful monitoring of the cardiologist's received dose is very important [9,10].

The current dosimetry methods, an example of which is film badge, are not interesting to be applied anymore due to the low accuracy in measurement and time duration needed for the accessibility of the results [11,12]. Therefore, they should be replaced by new dosimetry methods among which the use of Thermoluminescence dosimetry (TLD), electronic monitoring, and simulation computerized methods is recommended [5]. Using personal dosimeters, such as TLD and electronic personal dosimeter (EPD), in interventional radiology (IR) has limitations, such as the inaccessibility of the effective dose and dose of extremities, which are due to the nature of IR procedures [13].

The Monte Carlo simulation method is an appropriate technique for dosimetry which has been widely used [14]. Due to the complication of physical dosimetry methods in the measurement of radiation exposure and the long time needed to be performed, the Monte Carlo simulation method is a realistic means for the investigation of patient's and cardiologist's doses [15]. On the other hand, in the angiography procedures, the patient is under the primary beams, and the received exposure is expressed by dose-area product (DAP); however, the cardiologist is under the scatter beams arising from the table and the surrounding equipment; therefore, the exposure of cardiologists is generally described by the personal dose equivalent (Hp[10]) [16]. Accordingly, the operator's dose is higher than that of the patient. For this reason, in recent years, the research teams have made attempts to investigate the relationship between the patient's recorded DAP and the cardiologist's dose during the cardiac fluoroscopy.

There is a method using a code that simulates the transport of the radiation, the absorbed dose to the organs and tissues by the Monte Carlo method, thereby determining the conversion coefficients (CCs) normalized to a dosimetric quantity which is directly measurable [17]. Therefore, regarding the radiological protection scope, there is a need for systematic dose CC tables that could allow the effective and equivalent dose estimation in procedures in IR [10]. It seems that by the new generation of fluoroscopy devices that are equipped with area product dosimeter or DAP-meter and can record the amount of produced does in different areas of the patient's body in each process, it is possible to calculate the cardiologist's dose by simulation and develop a relationship between the patient's DAP and cardiologist's dose. This relationship can also be in the format of a suitable conversion factor. With this background in mind, the present study investigated the correlation between the patient's dose and cardiologist's dose using Monte Carlo simulation.

Materials and Methods

This study aimed to investigate the relationship and correlation between the two variables of DAP and cardiologist dose during CA. In this study, Monte Carlo simulation and measurement by a personal dosimeter were used as dosimetry methods.

Monte Carlo Simulation

The simulation was carried out using the Monte Carlo code Monte Carlo N-Particle extended (MCNPX; version 2.6.0). In all the simulations, the energy spectra, filtration, and field size were kept constant. The field size in this study was 20×20 cm^2, defined in the plane perpendicular to the X-ray beam central axis and the patient surface. The patient's table was modeled as a 150×54×4 cm^3 box made of carbon fiber. In this study, two types of tally F6 and *F8 were used. The F6 tally was used for the calculation of the tissue-equivalent doses in this study. F6 tally expresses the average of stored energy in a cell in a unit of $MeV.g^{-1}$, and *F8 tally was used for expressing the energy distribution of the pulses created in the detector [14]. In MCNPX simulations, some 2×10^9 particle histories were run; this gives a statistical uncertainly of less than 1% for the results.

Characteristics of Beam Source

The focal spot was in the form of a point source on the Z axis under the patient's table; the X-ray beam with a cone angle and the square cross-section was emitted from this source hitting the dorsal surface of the patient's body.

Four lead collimators with the dimensions of 10×10×1 cm^3 were placed at a distance of 7 cm from the focal spot to limit and direct the photons to the surface of the beam in a way that a small field was made between them. The required parameters for writing the energy spectra included the tube voltage, beam filtration, and anode angle. In the present study, the simulations related to three spectra of 70, 81, and 90 kVp with 4.5 mmAl were written as the inherent filtration with an anode angle of 12°. For the validation of the simulation program, it was needed to write the programs. The simulation programs for the measurement of Half Value Layer (HVL) and determination of the ratio of dose level under and over the phantom on the track of primary beam were among these programs. In addition, a program was written for the determination of the ratio of DAP to the cardiologist entrance exposure. The following section explains all the above-mentioned programs.

Simulation Program for Determination of HVL

The used geometry in this program was as follows:

The focal spot was placed in the form of a point source at a distance of 50 cm from the center of the coordinate in the line of the negative Z axis (Z=-50). Four collimators were placed in the interval distance of 7 cm upper the focal spot in a form that a square field with the dimensions of 0.35×0.35 cm^2 was formed between them. The farmer dosimeter was defined in an air-filled sphere with a radius of 1 cm placed in the line of the positive Z axis (Z=+50). The distance of the focal spot to the dosimeter was 100 cm. The size of the field in the place of the dosimeter was 5×5 cm^2.

The defined geometry for the calculation of the HVL and the output was obtained in two forms as follows:

Dosimeter reading was performed without aluminum, and dosimeter reading was performed so that the aluminum filters with different thicknesses were placed in the primary beam path.

Simulation of Dosimeter Readings in Primary Beams

The applied geometry in this program was as follows:

The focal spot in the coordination of Z=-64 cm was placed on the table. Four collimators were placed about 7 cm above the focal spot in a way that a square field with the dimensions of 2.18×2.18 cm^2 was opened between them. The simulation of the room space and farmer dosimeter was similar to the program related to the calculation of HVL. In addition, the center of coordinates is considered on the surface of the table. The water phantom was in the form of a rectangular cube with the dimensions of 70×40×20 cm^3 that was placed on the table in line with the Y axis.

In this program, the output was obtained at two points, namely in the place of the dosimeter under the water phantom and the dosimeter place on the water phantom. Finally, the relationship between these two outputs was obtained that should be equal to the ratio of dosimeter readings in the experimental measurement conditions.

Simulations to Determine Correlation Between DAP and Cardiologist Entrance Exposure

The main purpose of writing this program was to obtain the correlation coefficient between the patient's body surface dose and the entrance dose to the cardiologist's body. For writing this program, the same validated spectrum as the previous programs was used. The applied geometry in these programs was as follows:

The tube was considered a point source, and the focal spot in the coordination Z=-76 was placed on the table. Four leaden collimators were placed in the form of a square field with dimensions of 0.92×0.92 cm^2 to be opened between them.

The size of the field in place of the flat detector was equal to 20×20 cm^2; therefore, in the place of the patient, it was equal to 10×10 cm^2. The protection devices inside the room included a leaden drape and the ceiling suspended screen shield, which had a thickness of 0.5 mm equal to the lead. They were defined in the simulation in the form of cubic cells with specified dimensions. The patient's table was simulated just as the previous programs. The phantom used in this program was ICRU (International Commission on Radiation Units and Measurements) standard spherical phantom.

ICRU Sphere Phantom

This is an ICRU special spherical phantom. The diameter of the sphere is equal to 30 cm, and its density is equal to $1\, {}^{g}/_{cm^3}$ consisting of the materials equal to the tissue, namely 76.2% oxygen, 11.1% carbon, 10.1% hydrogen, and 2.6% nitrogen. It adequately approximates the human body as to the scattering and attenuation of the radiation fields under consideration [18]. The DAP quantity is the patient's dose representation, and the dosimeter reading is the representation of the cardiologist's dose.

Calculation of DAP From Simulations

Some quantities, such as DAP or Kerma Air Product (KAP), are independent of the distance of the focal spot to the measured point. For the calculation of the DAP or the irradiated surface dose of the patient's body, a space with specified dimensions of 10×10×1 cm^3 from the air between the patient and table was considered; the obtained amount of the output from this space is on the surface of the patient's body. For the calculation of the DAP, this amount of dose should be multiplied by the irradiated area of the patient's body [14].

Calculation of Cardiologist's Dose from Simulations

For the calculation of this amount, the output should be obtained at the place of dosimeter installation on the cardiologist's chest. For this purpose, a small sphere of the air with a radius of 0.5 cm was defined. Assuming that the cardiologist with the height of 180 cm stands at the distance of 25 cm from the table, upside the surface of the patient's waist, the placed dosimeter on his chest was at the height of 150 cm from the floor.

These simulation programs were written in three different spectra of 70, 81, and 90 kVp and six different angles of tube rotation. Therefore, we had 18 programs with different energy spectra and different angles of tube rotation. In each of these programs, the output was obtained in two places, one cell related to DAP and the other to the cardiologist's dose. The program was run, lasting about 2 weeks using the number of particles equal to 2×10^9.

Validation of Simulations with Practical Measurements

Since each simulation program for confirmation needs to be validated, some practical measurements should be performed in the hospital. These practical measurements were performed in the Angiography Department of Shiraz Shahid Faghihi Hospital, Shiraz, Iran.

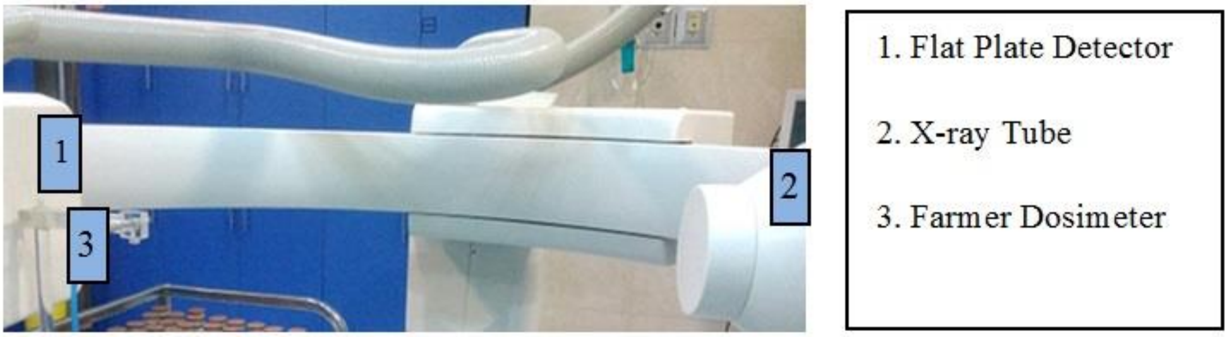

Figure 1. Measurement Geometry for Determination of Half Value Layer of Spectrum Energy 81 kVp, Determining Exposure in Two Points in Track of Primary Beam with Water Phantom

The mode of fluoroscopy system of this department is Siemens Artis Zee that is equipped with a DAP meter and can record the doses received by the patient in each procedure. The practical measurements of this study include HVL calculation and a series of other factors, such as calculation of the dose in different conditions and use of the water phantom and Rando Phantom.

HVL Conclusion

The angiography systems are usually automatic; however, for the conclusion of HVL, the beam conditions should be fixed during the measurement.

Accordingly, the device should be turned to manual mode. This feature was possible only by changing the settings of the device by installation engineers. After exiting the device from automatic mode, the beam conditions in the manual form could be selected. The selected beam parameters for all the angles were equal to 81 kVp and 69 mA, and they were fixed. For the calculation of HVL, the tube was placed in the 90 degree or lateral so that the table exit from the primary beam path. Any additional subject should be on the way of the beam to produce a scatter beam. The dosimeter was placed in the line of the tube at the interval distance of 100 cm from the tube. The aluminum layers were placed at a distance of 50 cm from the tube in the path of primary beams.

Figure 1 shows the geometry of this measurement. The size of the field in the place of the dosimeter should be a size that can be placed about 1.5 cm surrounding the head of the dosimeter inside the field. The processes started after setting the conditions of the beam and geometry of measurement.

First, the beams were measured without using the aluminum filter between the X-ray tube and dosimeter. Then, the thickest part of the filter was put in the path of the X-ray, and the measurement was performed. In the next processes, different thicknesses were put against the beam, and the dosimeter reading was recorded. Meanwhile, each measurement was repeated three times. With the obtained data pairs (i.e., the thickness of absorption material and the intensity of beam related to that) through the Figure, the HVL and the second HVL could be calculated.

The purpose of this measurement was to determine the exposure value in two points in the track of primary beams with water phantom. One point was in the place of the heart under the phantom and the other one in the same place but over the phantom. As to the geometry of the measurement, the X-ray tube under the table was put so that the interval of the focal spot to the upper surface of the table was equal to 64 cm. At the same time, the dosimeter was placed under the phantom and the other time over the phantom; in both conditions, the beam was exposed. Meanwhile, each measurement was repeated three times.

The Second Method: Measurement with a Personal Dosimeter

Another practical process of this plan was the cardiologist’s dosimetry in real conditions. This dosimetry was performed for 3 weeks in the Cath Lab Department of Shiraz Shahid Faghihi Hospital. For this purpose, 25 CA procedures were investigated.

The type of used dosimeter was EPD model Mini 6100 that was placed on the lead apron in the chest region of the cardiologist. From the beginning to the end of each procedure, the dosimeter reading was recorded; it was the same as the cardiologist’s dose during the procedure. Moreover, at the end of each procedure, the patient’s DAP data file was obtained from the device control system. In this file, in addition to the DAP value in different angles of tube rotation, the total DAP, which is the result of the sum of DAP_{cine} and $DAP_{fluoroscopy}$, was recorded during the total time of the procedure. During this time, in each procedure, the dosimetry data, including dosimeter reading and total DAP of the procedure, were recorded.

Results

The HVL value of 81 kVp spectrum was obtained from the practical measurements, equal to 0.23 cm of aluminium. Therefore, this simulated spectrum will be confirmed for calculating HVL. Table 1 shows the results of this simulation. The division of the two values was obtained on a 2/0.3, which is almost the same as 2.

Table 1. Output Obtained From a Simulation Program to Determine Half Value Layer

Error percentage	Tally *F8	Aluminum filter
0.0017	8.07984×10-12	0
0.0023	3.96486×10-12	0.23

Table 2. Output Obtained From a Simulation Program to Determine Dose Ratio at Two Points in Direction of Primary Beams

	Error percentage	Tally *F8
Under the phantom	0.01	2.305858×10-10
Over the phantom	0.01	2.71357×10-12

The amount of the dose at two points in the direction of the primary beams, using the method of measuring the dosimeter readings under the Phantom to the readings over the Phantom, was obtained equal to 84/97. This ratio, shown in the results of simulation in Table 2, was calculated equal to 83; this small difference between them can be overlooked.

Results of Simulation to Determine Correlation between Level of Cardiologist Exposure and DAP

For the determination of the correlation between DAP and surface exposure of the cardiologist using simulation, three energy spectra (i.e., 70, 81, and 90 kVp) and six different tube rotation angles were simulated. In each simulation, the output was taken in two places. One cell was related to the DAP and another to the cardiologist's dose, as shown in Table 3. Tally F6 in terms of output was taken in MeV/gr. For the calculation of the CA, it is needed to do some conversions; it means that the output value of DAP in $Gy.cm^2$ and amount of cardiologist's dose in µSv were obtained. Table 4 shows the statistical analysis of values of dose and DAP obtained from simulation.

For the investigation of the correlation between the two variables (i.e., DAP and cardiologist's dose in the simulation), regression analysis was carried out between these two variables, and Figure 2 shows this ratio in correlation.

In the second method of this study, the measurement with a personal dosimeter, DAP values for the patient and cardiologist's doses in 25 CA test was recorded, and the results are listed in Table 5. Table 6 shows the statistical analysis of dose and DAP obtained from measurements of the patient. In order to evaluate the correlation between the obtained DAP and cardiologist's dose from 25 CA, regression analysis was performed, and Figure 3 shows the results.

Table 3. Outputs Obtained From Simulation to Determine Dose and Dose-Area Product

		PA	LAO60	LAO30	RAO30	CR20	CA20
Cardiologists dose×10^{-16} (µSv)	70 kVp	8.306176	4.76968	9.86168	9.804224	8.765216	8.16256
	81 kVp	7.495072	4.993264	7.48152	8.384576	9.682928	7.236896
	90 kVp	8.4164	5.453376	9.292528	9.02384	7.855232	8.033424
Dose-Area Product×10^{-16} ($Gy.cm^2$)	70 kVp	3.28544	1.722992	3.132512	3.132528	3.220752	3.221072
	81 kVp	9.804224	1.729072	3.047344	3.047296	3.122032	3.122224
	90 kVp	3.110384	1.73312	2.99544	2.99544	3.061664	3.062

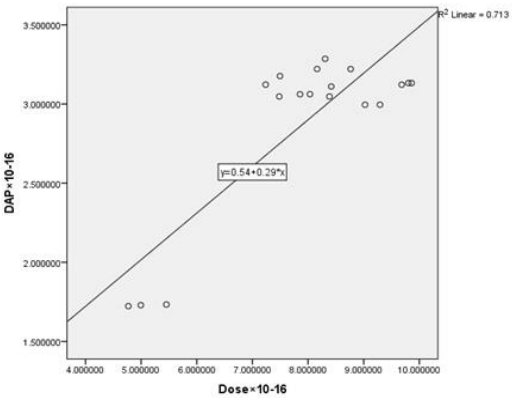

Figure 2. Diagram of Relationship between Obtained Dose and Dose-Area Product (DAP) From Simulation

Table 4. Statistical Analysis of Output Obtained From Simulation to Determine Dose and Dose-Area Product

Variable	n	Min	Max	Mean±Standarad deviation
Dose-Area Product ×10^{-16}	18	1.723	3.285	2.884±0.537
Dose×10^{-16}	18	4.770	9.816	7.945±1.540

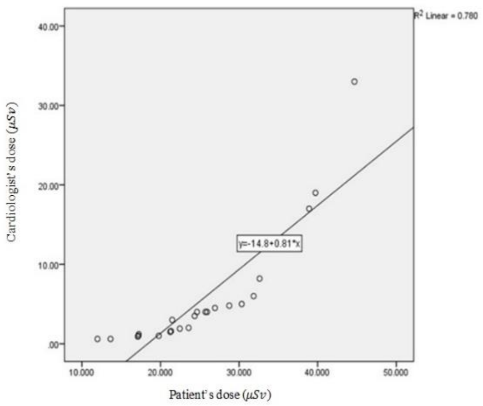

Figure 3. Diagram of Relationship between Measured Dose of Cardiologist by Electronic Personal Dosimeter and Dose-Area Product Value in 25 Exams of Cardiac Angiography

Table 5. Measured Values of Dose and Dose-Area Product at 25 Exams of Heart Angiography

Exam no.	Dose-Area Product (Gy.cm^2)	Cardiologist's dose (µSv)
1	11.98	0.6
2	13.64	0.6
3	19.77	1
4	17.11	0.9
5	25.72	4
6	21.49	3
7	22.46	1.9
8	17.23	1.2
9	23.58	2
10	31.85	6
11	38.91	17
12	25.93	4
13	32.61	8.2
14	24.64	4
15	17.18	1
16	26.93	4.5
17	33.65	12
18	39.72	19
19	28.75	4.8
20	34.2	12.8
21	21.34	1.58
22	44.68	33
23	21.23	1.5
24	30.33	5
25	24.35	3.5

Table 6. Statistical Analysis of Dose and Dose-Area Product Obtained From Measurements of Patient

Variable	Min	Max	Mean±Standard deviation
Patient's dose	11.980	44.68	25.97±8.28
Cardiologist's dose	0.60	33	6.12±7.55

Discussion

Looking for the validation of the simulated spectrum by calculation the HVL, it was seen the thickness of 0.23 cm Aluminium as HVL at 81 kVp spectrum obtained from the practical measurement, applies in the simulated program. Moreover, in the second method of validation, the exposures in two points in the track of primary beam, ratio of dosimeter reading under the phantom, and value over the phantom in the two used methods of measurement and Monte Carlo simulation (with a minor difference) were almost equal. Accordingly, by the use of these two methods of validations, it was possible to confirm the simulation spectrum of this study.

Determination of Correlation and Relationship between DAP Values and Cardiologist's Dose Using Simulation and Measurement Methods

As in figures 2 and 3 illustrating the relationship between the values of dose and DAP using Mont Carlo simulation, it was concluded that among the data obtained from 18 simulation programs related to three energy spectra of 70, 81, and 90 kVp and six tube rotations of different angles, there was a relatively strong linear relationship with the correlation coefficient of R^2=0.71 between the two variables of physician's dose and DAP value. Likewise, the obtained results of dosimetry conducted on the patients in the 25 CA procedures showed that there was a relatively strong linear relationship with the correlation coefficient of R^2=0.78 between the two variables of cardiologist's dose and DAP.

In a study carried out by Kuipers et al. in 2010 [16], a linear relationship was observed between the dose over the apron of a cardiologist in the chest region and recorded DAP during each cardiac fluoroscopy procedure. In the aforementioned study, the physicians were monitored during the CA procedures and angioplasty (PTCA) by personal dosimeters. The dosimeter used in this study was TLD 100 which was placed in special covers and installed at a special point on the physician's chest. After doing calculations, a linear relationship was observed between these two variables, with a linear correlation coefficient of R^2=0.55. This result confirms numerous reports of ICRP based on the appropriation level of physician exposure to the total recorded DAP during the patient exposure.

The comparison of the results obtained in the study conducted by Kuipers et al. to those of the present study revealed that the linear correlation between the dose over the apron of the physician in the chest region and recorded DAP increased from R^2=0.55 to R^2=0.7 in the present study. This improvement is due to several factors as follows:

1- In this study, all the measurements were performed for a physician; however, in the study performed by Kuipers et al., the measurements were performed for seven cardiologists. This might have caused the difference between the results of the two studies because it is obvious that each physician, depending on his/her skills and work experience, uses the views and the conditions specific to him/her and acts differently, compared to other physicians, as to the distance of physician from the patient and the way he or she uses the protection devices, especially ceiling suspended glass shield and table-mounted drop shield. In the simulation conducted in this study, there was no displacement in the standard position of the physician to the patient and the installation place of the protective devices.
2- The second factor that may be effective in the obtained results of this study is the choice of the dosimeter. The type of dosimeter used in the present study was EPD; its measurement error in comparison to the dosimeters of TLD 100 is much lower and gets less effect from the confounding factors [1].
3- The third factor that may have a considerable effect on the improvement of the results of this part of the study is the type of fluoroscopy examination of the coronary arteries. In the study performed by Kuipers et al., the results of angiography and angioplasty procedures were presented; however, all the patients in the measurements method of this study and the Mont Carlo simulation method were under CA procedures. The effect of this factor is caused by the difference in cardiologist's exposure during angiography and angioplasty procedures of coronary arteries. In angioplasty procedures, due to the increased time of the patient's exposure, the physician's exposure is more, compared to angiography.
4- In the study performed by Kuipers et al., the sample size was not mentioned; nevertheless, in the simulation method of the present study, a phantom was selected the same as a mean size patient. However, the patient's size and weight are so important in the rate of the physician's exposure.

In a study performed by Bahreyni et al. in 2014 [6], it was observed that there was a strong linear relationship between DAP and the received cardiologist's exposure, with the correlation coefficient of R^2=0.88. In a comparison of the results of the study by Bahreyni et al. and the obtained results of measurement in the present study, it was observed that the correlation between the dose of physician's chest region and recorded DAP decreased from R^2=0.88 to R^2=0.78.

This reduction of correlation may arise due to the following factors:

1- The patient's weight was determined as an effective factor in the cardiologist dose in the present study; nonetheless, in the study performed by Bahreyni et al., a phantom was used with the mean weight instead of a patient.
2- In the study conducted by Bahreyni et al., the correlation between the two variables of different views of imaging was obtained from one procedure; however, in the present study, the correlation between the dose and total DAP was obtained from 25 various procedures.

When this correlation, rather than one procedure, is investigated in several procedures, there is no doubt that more factors are effective in the cardiologist's dose; as a result, its correlation is effective in DAP. For example, the position of the physician might be displaced, his/her distance from the patient is changed, or the place of ceiling suspended shield is displaced to some extent; nevertheless, in a procedure, these factors are almost without any changes. In the comparison of the results obtained by Bahreyni et al. with those of this study, it was observed that the correlation between the dose of physician's chest region and DAP decreased from R^2=0.88 to R^2=0.71.

The most important reason for this reduction is the fewer simulation data of the present study. In the study performed by Bahreyni et al., the correlation between the two variables in 77 views of imaging was calculated; however, in the present study, the correlation between two variables was presented in 18 different modes of simulation.

The importance of radiation monitoring, especially in IR departments, is not at stake [19]. This study proposed and evaluated a useful and simple method for this measurement. Upgrading these methods can help the health.

Conclusion

In conclusion, it can be mentioned that the reason for the variety of the results obtained in several studies is the difference in the accuracy of the methods used in each of these studies. In other words, the effective factors in the cardiologist's dose should be accurately considered. These factors include the patient's weight, type of procedures (i.e., CA or PTCA), skill and experience of the cardiologist, and number of reviewed views. All these factors are effective in the dose received by the cardiologist; as a result, the correlation coefficient is effective between DAP and cardiologist's dose.

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