Radiation Dose to Patients during Coronary Angiography and Percutaneous Transluminal Coronary Angioplasty

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Abstract

Coronary Angiography (CAG) and Percutaneous Transluminal Coronary Angioplasty (PTCA) procedures are now widely performed in different cardiac hospitals in Bangladesh. Patients undergoing CAG and PTCA procedures can be subjected to large radiation dose. Two catheterization laboratories in Square Hospital, Dhaka were chosen to measure the radiation dose of patients by Thermoluminiscence Dosimeter (TLD) chips. A total of calibrated 96 TLD chips packed in a polythene sheet were used for the measurement of effective dose of the patient. Patients went through CAG received average effective dose 19.32 mSv while those who underwent PTCA received average effective dose 169.50 mSv. These larger values may have been caused due to long fluoroscopy time and large number of cine frames. The overall dose distribution was found to be normal during CAG procedure whereas it was left or right skewed in the PTCA. This is probably due to the fact that x-ray tube is kept in the normal position in CAG but for the PTCA the tube is held either in the left or right side during left or right coronary angioplasty, respectively.

Keywords: Thermoluminiscence Dosimetry, Fluoroscopy, Lithium fluoride crystal, Coronary angiography, Coronary angioplasty, Radiation dose, Maximum permissible dose

1. Introduction

Over the last ten years the number of interventional cardiology (IC) procedures such as Coronary Angiography (CAG), Percutaneous Transluminal Coronary Angioplasty (PTCA), has increased rapidly [1,2]. The main reason is that IC permits specialists to avoid complicated invasive surgery which some patients might not be able to tolerate due to factors of age or pathology and results in limited hospitalization [3]. Additionally, as knowledge of the benefits of IC becomes more widely spread, more complicated procedures are technically possible.

Radiation in cath lab during IC is generated using two different modes: Fluoroscopy and cine angiography (cine). Fluoroscopy is used for catheter placement and involves 95% of the total X-ray operation time but only causes 40% of the total radiation exposure to staff and patients. Cine is used to acquire diagnostic images and to generate a permanent record and although representing only 5% of the total X-ray tube operation time, 60% of the total radiation exposure to staff and patients occur during cine.

The medical use of ionizing radiation, while offering great benefit to patients, contributes significantly to radiation exposure of individuals and populations [4]. Interventional radiology and interventional cardiology contribute a significant dose to the occupational workers and patients from medical exposures. When complex procedures are performed or procedures are repeated for the same patient, high radiation dose can occur because procedures often requires long fluoroscopy time and long number of images[5].

Compared to other departments (radiology, urology, operating rooms, etc.) that also use X-ray equipment, the cardiac cath lab is generally considered an area where exposure to radiation is particularly high [6]. Factors such as the configuration of the X-ray equipment, the number of cases per day and the often long period of screening required for a study, contribute to this relatively high level of exposure.
Coronary Angiography (CAG) and Percutaneous Transluminal Coronary Angioplasty (PTCA) procedures are now widely performed to diagnose cardiac function as well as to treat heart ailments in different cardiac hospitals in Bangladesh. Patients undergoing CAG and PTCA procedures can be subjected to large radiation exposure due to long fluoroscopy time and large number of cine frames.

Exposure to ionization radiation may result in adverse health effect on patients, cardiologists, technologists and on their progeny. The patient and occupational doses in interventional cardiology tend to be higher compared to other medical practices as a result of the recent increasing use of interventional technique. Unfortunately physicians and technicians are dramatically unaware of dose, long-term risks and population health impact caused by the use of medical ionizing radiation.

It is important to effectively measure radiation dose acquired by patients for their betterment. By assessing the measured dose technical personnel as well as authority could take necessary actions to reduce dose as low as reasonably achievable (ALARA). The main objective of this study is to measure and assess radiation dose of the patients who are undergoing CAG and PTCA procedures.

2. Materials and Methods

The effective atomic number of dosimetric LiF (effective Z=8.18) is close to that for soft tissue (effective Z=7.4) and for air (effective Z= 7.65). Hence for identical exposures to radiation, the amount of energy absorbed by LiF is very close to that absorbed by an equal mass of soft tissue. For this reason, LiF is widely used for the measurement of radiation doses within staff member, patients, personnel dosimetry and other dosimetric measurement. In the present study, Lithium Fluoride (LiF) with impurity doping in the form of chips having commercial names of TLD-100 (natural isotopes with ratio of 7.5% Li and 92.5% F and of size 1/8 inch x 1/8 inch x 0.035 inch and weighing about 24 mg) have been used as TLD and these chips were imported from Harshaw Chemical company, Cleveland, Ohio, USA.

The Model 2210 is a rotating disk irradiator with a $^{90}\text{Sr} / ^{90}\text{Y}$ source (Nominal activity: 33 MBq (0.917 mci)) was used to irradiate thermo luminescent (TL) elements in the form of chips; the unit is portable and designed for bench top mounting. The TL samples were placed in recesses on the periphery of disk; as the disk rotates, the samples move into the radiation beam. The irradiator was calibrated by BICRON Technologies. The average $^{137}\text{Cs}$ equivalent dose determined to be 6.90 mSv for 100 revolutions [7].

Thermal Treatment before the irradiation was carried out to optimize the trap distribution in TL material and to make empty previously filled high temperature traps. A muffle furnace, Model: 10A-1A, manufactured by Blue M Electric Company, Illinois, U.S.A, was used for annealing the TLD chips. This furnace automatically controls the temperature and has a range from 0°C to 1000°C. TLD materials were stored in special circular glass container made of Pyrex, during thermal treatments. TLD chips were annealed before using to remove any dose or background radiation absorbed prior to perform any exposure of interest. For this purpose the chips were first clean by the methanol liquid and allowed to dry in air by placing these chips on a Petri dish [8]. The Petri dish was then placed into the muffle furnace to anneal the chips at 400°C for 1 hour, then cooled at room temperature and again annealed at 100°C for 2 hours.

In this work we have used the Harshaw TLD system Model 3500 Manual TLD Reader. The Harshaw TLD System 3500 Manual TLD Reader is a PC-driven, manually operated, tabletop instrument to read TLD chips. The 3500 TLD Reader read one dosimeter per loading.
A total of 99, with 11 rows and 9 columns covering the whole back from shoulder to waistline of a patient, TLD chips were packed in plastic bag as shown in the Fig. 1, the chips were attached with cello-tape to the centre. Finally, 96 chips were used because three chips (83, 98 and 99) were broken at the time of annealing.

For the purpose of the present study data were collected from two catheterization laboratories in Square Hospital, Dhaka. X-ray doses to patients during 8 CAG procedures and 4 PTCA procedures were collected and enlisted in this study. The sample was random and included male and female patients during August 2011 to November 2011. A total of 96 TLD chips were packed in polythene sheet. Then the sheet was kept on the bed of the patient shown in Fig. 2 and thus doses were collected for the study. The irradiated chips were read out using automatic TLD reader HARSHAW 3500 (Germany). The read out was at a 55°C preheat temperature and the signal was acquired from 55°C to 260°C with heating rate of 11°C/s.

![Fig. 1: Schematic arrangement of TLD chips, three chips, 83, 98 and 99, were broken at the time of annealing, for the measurement of patient dose.](image)

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![Fig. 2: Polythene sheet (with TLD chips) on the bed of patient, x-ray tube as a source of radiation is seen under the bed.](image)

### 3. Results and Discussion

Patient dose monitoring was performed in the catheterization laboratories of Square Hospital Ltd. Dhaka. Eight patients (5 males, 3 females) who underwent CAG, four male patients who underwent PTCA were enrolled in this study.

From Fig. 3 it is seen that the patients who underwent CAG have average effective dose 19.32 mSv, while those who underwent PTCA have average effective dose 119.50 mSv as is shown in Fig. 4. Moreover the dose pattern shows around eight cycles with gradual increment and decrement of the values of average dose, this is
because the chips were distributed in nine columns, each column, having eleven chips, started from patient’s shoulder to downward till waistline. There is a remarkable observation as seen from the Fig. 3 that the overall dose distribution is normal during CAG, whereas for PTCA as seen in Fig. 4 the overall dose distribution is left or right skewed instead of middle. The reason for such different behavior is probably due to the method of exposure in the two procedures. During CAG the gantry rotates through equal angles (around 18°) and spray die to monitor cardiac functions and after spraying the die it stays at the middle position. On the other hand during the procedure of PTCA the x-ray tube remains most of the time at left or right side during left or right coronary angioplasty.

In this study the average value of DAP was 5256 cGy cm² for CAG which was comparable with the values found by the study of V Tsapaki[9] and by Vano[10], the values were 4730 cGy cm² and 6650 cGy cm², respectively. The average value of DAP found for PTCA procedures in this study was 45870 cGycm². On the other hand V Tsapaki[9] and Vano[10] found 6800 cGy cm² and 8750 cGycm², respectively. The DAP value found in our study is much larger than those found by the researchers mentioned here. The larger value of DAP found in this study may have been caused due to long Fluoroscopy time, large number of cine frames and more running time of cine camera. in other country, so it is a matter of great concern. Efforts should be taken to minimize the value of DAP readings during PTCA procedures.

![Fig. 3: Average measured dose in 96 TLD chips during CAG.](image)

![Fig. 4: Average measured dose in 96 TLD chips during PTCA.](image)
The Fig. 5 depicts the average dose of 12 patients. During PTCA procedure, the highest average dose was 258.22 mSv, on the other hand the lowest average dose was 124.82 mSv. While during CAG procedure, the highest and the lowest average dose were 29.28 mSv and 10.90 mSv, respectively.

It is seen that the four patients who were under went PTCA received more than nine times dose with respect to the other eight patients who underwent CAG procedure. If the average dose received by the patients is compared with the x-ray time taken to perform the procedure, it is observed that the average dose is very much correlated with x-ray time as is shown in the Fig. 6 and the Table 1 shows that the correlation coefficient is 0.91.

Fig. 5: Average dose of 4 patients during PTCA and 8 patients during CAG procedures.

Fig. 6: Distribution of patients’ dose and x-ray time during CAG and PTCA procedures.
The highest time 52.8 minutes was taken during the PTCA procedure for which the highest dose was recorded and the dose-area product value was 51868 cGy-cm$^2$ which was taken from DAP meter.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>DAP (cGy-cm$^2$)</th>
<th>Fluoroscopy Time (min)</th>
<th>Avg. effective dose (mSv)</th>
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<tbody>
<tr>
<td>CAG</td>
<td>2794</td>
<td>5.0</td>
<td>21.92</td>
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<tr>
<td>CAG</td>
<td>5970</td>
<td>4</td>
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<td>CAG</td>
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<td>15.48</td>
</tr>
<tr>
<td>CAG</td>
<td>4125</td>
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</tr>
<tr>
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<td>21260</td>
<td>50</td>
<td>124.82</td>
</tr>
<tr>
<td>PTCA</td>
<td>51312</td>
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</tr>
<tr>
<td>PTCA</td>
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<td>52.8</td>
<td>258.22</td>
</tr>
<tr>
<td>PTCA</td>
<td>58043</td>
<td>49.6</td>
<td>125.44</td>
</tr>
</tbody>
</table>

Correlation Coefficient 0.91

It is found from the pie charts Fig. 7 that 83% cardiac patients were of the age of more than 40 years and only 17% were less than 40. It is also observed that the patients who underwent PTCA and CAG procedures, 83% of them were more than 60 kg and only 17% were less than 60 kg.

4. Conclusions

The main objective of this study was to provide information about patient dose, which is intimately correlated with occupational dose, in interventional cardiac procedures through the measurement of radiation dose to patients undergoing CAG and PTCA procedures.

The study presents results for 12 patients undergoing coronary angiography and angioplasty at two catheterization laboratories of Square hospital, Dhaka. It was observed that the patient who underwent PTCA got comparatively large amount of dose. To reduce the dose as low as reasonably achievable; education and training on radiation hazard, and awareness in radiation protection is now imperative.

It is impossible to prescribe specific radiation protection measures which could be universally applicable to all cardiac catheterization laboratories. Each laboratory can reduce radiation exposure by applying certain general radiation protection principles to its individual needs. Some practical suggestion to improve patient radiation protection:

(i) Always use the least amount of time necessary to accomplish the procedure.
(ii) If temporal resolution is not needed (e.g. guiding a catheter from a femoral artery to aortic arch) use pulsed fluoroscopy.
(iii) Running time of Cine camera, for recording image on 35 mm film, should be minimized.
(iv) Use of low frame rate pulsed fluoroscopy instead of continuous.
References


