# PATIENT AND STAFF EXPOSURE DURING CARDIAC CATHETERIZATION

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## ABSTRACT

The purpose of this study was to estimate both patient and staff radiation doses during coronary angiography and percutaneous transluminal coronary angioplasty with stenting procedures by direct measurement and to compare these results with data from the literatures. Radiation doses from 159 patients have been studied, 101 of which had undergone coronary angioplasty and 58 percutaneous transluminal coronary angioplasty with stenting. All procedures were undertaken on biplane angiocardiographic system (Phillips Integris). The system performed under automatic exposure control using continuous fluoroscopy and cine frame rate of 12.5 frames $s^{-1}$. Dose–area product values and fluoroscopy times were collected for each patient. Median values for dose–area product were 39.3 Gy $cm^2$ for coronary angiography and 146.7 Gy $cm^2$ for percutaneous transluminal coronary angioplasty with stenting. Median fluoroscopy time was 3.8 min and 17.7 min for coronary angiography and percutaneous transluminal coronary angioplasty with stenting, respectively. Comparison showed that patient dose–area product values for coronary angiography were lower than other studies and fluoroscopy time values were comparable. But the patient dose–area product values and fluoroscpy time for percutaneous transluminal coronary angioplasty with stenting were higher than other studies. The cardiologist received a median dose of 253.9 uGy and 264.5 uGy to the lens of the eye, and 261.3 uGy and 256.5 uGy to the skin level of thyroid, per procedure of coronary angiography and percutaneous transluminal coronary angioplasty with stenting respectively. Recommendations for optimization of patient doses are given.

## INTRODUCTION

The number of interventional cardiology (IC) procedures has increased rapidly in recent years.[1-3] Coronary angiography (CA) and percutaneous transluminal coronary angioplasty (PTCA) are now widely performed as a matter of routine in many general hospitals and are considered safe procedures in the hands of experienced cardiologists. However, it is also known that these procedures are associated with high radiation doses due to long fluoroscopy time (T) and large numbers of cine frames (F). These levels of radiation may even lead to radiation skin injuries under certain conditions. The United States Food and Drug Administration (FDA), the World Health Organisation (WHO), the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) have published document[4,5] to avoid deterministic effects in cardiology procedures.

A number of studies[6-12] have been investigated

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for patient radiation doses in IC procedures, revealing variability not only in the methods of radiation measurement, but also in the level of radiation doses received by the patients. The complexity of the procedures, experience of the operators, level of training in radiation protection and type of X-ray equipment available in the catheterization laboratory are some of the factors that are responsible for the differences in results.

As there is no data available concerning patient and staff exposure doses during IR procedure in cardiac centers in Thailand. We designed to find out whether radiation exposure to patients and cardiologists undergoing CA and percutaneous transluminal coronary angioplasty with stenting (PTCA-ST) procedures will be in the trigger reference levels. The purpose of this study was to determine staff doses on the practice and patient doses in a major cardiac center in Bangkok, undergoing differences investigations and compare the results with those found in the literatures, in order to optimize angiographic and interventional cardiology procedures. Before the study commenced, approval was obtained from the local research ethics committee.

## MATERIALS AND METHODS

Information on routine practice of CA and PTCA-ST procedures in a major cardiac center in Bangkok was collected between April-July 2005. For the patients, the total doses of dose-area product and fluoroscopy times in the area of exposure were recorded. Concerning staff, the entrance surface doses (ESD) to the lens of eyes and thyroids were estimated by using thermoluminescent dosimeters (TLDs).

The cardiac catheterization laboratory studied is equipped with biplane angiocardiographic system (Phillips Integris; Phillips Medical Systems, Best, The Netherlands). The system performs under automatic control and continuous fluoroscopy mode. Radiation doses are measured directly during each procedure with a dose–area product (DAP) meter (Diamentor M1; PTW, Freiburg, Germany). DAP readings were independently obtained during fluoroscopy screening and image acquisition, their sum giving the total DAP. Patient height and weight, screening time and DAP readings were recorded for each procedure. Output constancy in the X-ray system were checked periodically, with satisfactory results. The DAP equipment was initially calibrated and verified in house.

All staff members are classified as occupationally exposed workers and are in consequence, already monitors by a regulatory dosimeter worn at chest/gonad level under apron. They all wear wrap around aprons during procedures, providing a protective of 0.50 mm lead equivalence at the front of the body and 0.25 mm lead equivalence at both sides and the back of the body. Since we were interested in the ESDs per procedure on parts of the body that were not protected by apron, additional measurements were performed by placing TLDs (lithium fluoride TLD-100 chips, individually calibrated for X-ray diagnostic energies from Harshaw TLD/Bicron/NE-Technology) on the forehead and neck of the cardiologist underwent CA and PTCA-ST.

## RESULTS AND DISCUSSION

During the study, 10 cardiologists performed 159 interventional cardiology procedures, of which 101 patients (63.5%) underwent CA and 58 patients (36.5%) PTCA-ST. For CA procedures, 57.4% were male and 42.6% were female, whereas for PTCA-ST, 65.5% were male and 34.5% were female. As may be deduced from Figure 1, the highest percentage of IC procedures was performed in patients in the age group of 50 years to 60 years. Radiation dose measurements in terms of DAP and fluoroscopy time (T) for CA and PTCA-ST were summarized in Table 1. The result of the ESD on the forehead and neck of a cardiologist underwent CA/PTCA-ST procedure was given in Table2.

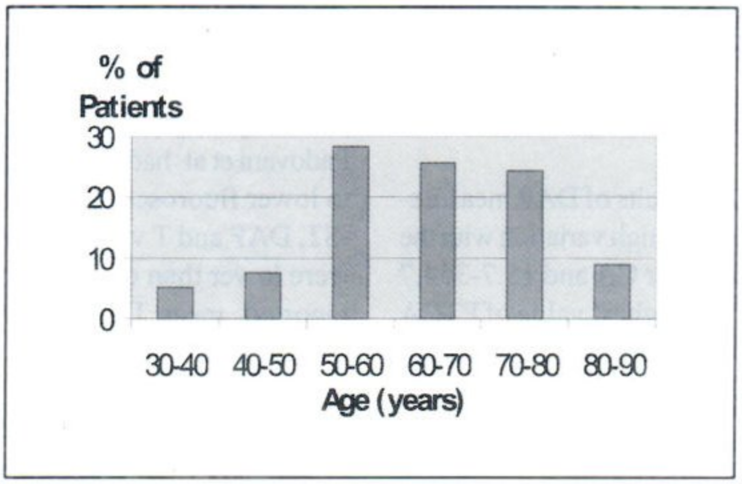


**Fig.1** Age distribution in coronary angiography and percutaneous transluminal coronary angioplasty (159 patients).

**Table 1** Dose-area product (DAP) results in Gy cm$^2$ and fluoroscopy time (T) in min for coronary angiography (CA) and percutaneous transluminal coronary angioplasty with stenting (PTCA-ST)

| Measurement | Type of procedure | Range | Mean ± SD | 1st quartile | Median | 3rd quartile |
|---|---|---|---|---|---|---|
| DAP (Gy cm$^2$) | CA (101 procedures) | 11.5-99.5 | 42.4 ± 19.8 | 26.2 | 39.3 | 53.7 |
| | PTCA-ST(58 procedures) | 15.7-354.7 | 152.4 ± 82.1 | 91.9 | 146.7 | 217.9 |
| T (min) | CA | 1.0-39.0 | 5.0 ± 4.4 | 2.7 | 3.8 | 5.5 |
| | PTCA-ST | 1.9-82.3 | 21.8 ± 15.0 | 11.9 | 17.7 | 31.7 |

SD, standard diviation

**Table 2** Data on entrance surface dose (ESD) to the eye and of cardiologist per CA or PTCA-ST procedure

| Procedure | | Sample size | ESD (uGy) per procedure | | | | |
|---|---|---|---|---|---|---|---|
| | | | Range | Mean ± SD | 1st quartile | Median | 3rd quartile |
| CA | Cardiologist | 10 | | | | | |
| | Eye | | 129.1-267.4 | 218.7 ± 55.2 | 168.9 | 253.9 | 261.7 |
| | Neck | | 158.6-272.8 | 227.4 ± 52.5 | 170.7 | 261.3 | 270.6 |
| PTCA-ST | Cardiologist | 10 | | | | | |
| | Eye | | 65.8-291.6 | 211.2 ± 96.1 | 150.0 | 264.5 | 267.8 |
| | Neck | | 163.1-281.4 | 232.2 ± 52.6 | 188.5 | 256.5 | 266.5 |

SD, standard diviation

Since the DAP and ESD values measured do not exhibit a normal distribution, as well as the mean and standard deviation, median and third quartile values have also been calculated.

Patients doses, the results of DAP measurements (Table 1) showed some high variation with the range of 11.5-99.5 Gy cm$^2$ for CA and 15.7-354.7 Gy cm$^2$ for PTCA-ST. The highest value of PTCA -ST (354.7) was already higher than a DAP trigger level[16] 300 Gy cm$^2$.

Staff doses, the data presented in Table 2 illustrated that the cardiologists received doses to the neck (represent thyroid) were higher than to the eyes (represent the lens of eyes) for both CA and PTCA -ST. Although doses to thyroid are higher, doses to the lens of eyes will be the critical organ relative to dose limits. Considering the annual dose limit to the lens of eyes of 150 mSv[17] for a classified procedures worker, and the 3rd quartile values presented in Table 2, a cardiologist can annually perform approximately 573 CA or 560 PTCA-ST procedures before reaching the dose limit. 3rd quartile values are used from a pragmatic radiation protection point of view. Nevertheless, doses to a staff can and should be decreased to a reasonably achievable level.[17]

Comparison of our results with results found in the literatures (Tables 3 and 4) showed that during CA; Vano et al,[6] Broadhead et al,[8] Zorzetto et al[9] and Tsapaki et al[13] had higher DAP values but Padovani et al[7] had slightly lower DAP values owing to lower fluoroscopy times (28%). During PTCA -ST, DAP and T values in the literatures for PTCA were lower than ours. Except Van De Putte et al[14] reported, mean DAP was 8% higher but for 3rd quartile DAP was 14.7% lower than our report.

The higher DAP and T values in our report for PTCA-ST can be explained by the fact that it is a therapeutic procedure that depends on the pathology of the patient. Bernardi[18] found an increase of T and total number of cine frames (F) in complex PTCA procedures. Padovani et al[19] found an increase of about 50% in radiation dose for medium complex procedures and an increase of 100% for complex procedures. However, these comparisons may have limited value, as in recent years a considerable effort has been made in Europe to improve radiation protection of the patient in interventional procedures through optimization programmes and technical improvement of the X-ray systems.

**Table 3** Comparison of this study with recent literature, in coronary angiography

| Author | N | DAP (Gy cm$^2$) | | | | T (min) | F |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Median | 3rd quart | Mean | Mean |
| This study | 101 | 42.4 | 19.8 | 39.3 | 53.7 | 5.0 | |
| Vano [6] | 288 | 66.5 | | 45.7 | 69.3 | | |
| Padovani [7] | 13 | 39.3 | 18.0 | | | 3.6 | 878 |
| Broadhead [8] | 2174 | 57.8 | | 45.5 | 69.9 | 5.7 | 689 |
| Zorzetto [9] | 79 | 55.9 | | 52.5 | 65.6 | 4.9 | 1350 |
| Tsapaki [13] | 195 | 47.3 | 27.9 | 39.1 | 60.4 | 6.5 | 1779] |

N, number of patients; DAP, dose–area product; T, fluoroscopy time; F, total number of cine frames; SD, standard diviation.

**Table 4** Comparison of this study with recent literatures, in percutaneous transluminal coronary angioplasty

| Author | N | DAP (Gy cm²) | | | | T (min) | F |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Median | 3rd quart | Mean | Mean |
| This study | 58 | 152.4 | 82.1 | 146.7 | 217.9 | 21.8 | |
| Vano[6] | 45 | 87.5 | 66.7 | 122.3 | | | |
| Padovani[7] | 54 | 101.9 | 84.9 | | | 18.5 | 1434 |
| Broadhead[8] | 214 | 77.9 | | 61.1 | 100.6 | 12.4 | 504 |
| Zorzetto[9] | 31 | 91.8 | | 82.6 | 104.6 | 12.2 | 1500 |
| Tsapaki[13] | 97 | 68.0 | 48.7 | 58.3 | 80.7 | 12.2 | 1914 |
| Van De Putte[14] | | 165.9 | | 131.6 | 185.8 | | |

N, number of patients; DAP, dose–area product; T, fluoroscopy time; F, total number of cine frames; SD, standard deviation.

In 2001, Neofotistou[15] published proposed reference dose levels (RDL) for IC procedures in terms of DAP, T and F which were derived from measurements taken by three European countries participating in an European concerted action concerning doses and images quality in digital imaging and interventional radiology. Her values were 67 Gy cm$^2$, 6 min and 1600 frames for CA and 110 Gy cm$^2$, 20 min and 1700 frames for PTCA. Comparison with our results for the proposed RDL, it was showed that the median radiation doses of this study are lower (DAP is 39.3 Gy cm$^2$) for CA and higher (146.7 Gy cm$^2$) for PTCA-ST, whilst fluoroscopy time are lower (3.8 min for CA and 17.7 min for PTCA-ST). Unfortunately, we have no information for the total number of frames to compare with other studies.

It was concluded that the staff doses in this study were found to be lower than the doses limits. For the patients doses, DAP and T values for CA procedure was lower than with the results found in the literatures. But for PTCA-ST, the DAP values they were higher than other studies and exceed the triggle level (300 Gy cm$^2$). In the event that the DAP trigger level was likely to be exceeded, addition informations on the techniques used [i.e. exposure parameters, beam projections, Image Intensifier (II) field sizes] should be recorded for a subsequent indirect estimation of the maximum skin doses and these patients should be clinically followed for possible skin injuries. Maximum skin dose is a good indicator for the onset of skin deterministic effects.[20,21] It is recommended that, continuous monitoring of patient radiation doses should be encouraged, not only for the patient safety, but also for the staffs involved.

**RDL** = Reference Dose Levels

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