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# Evaluation of cancer risk of the patients undergoing coronary angiography in Yazd, Iran

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*Background:* Coronary angiography is a commonly performed diagnostic procedure with life saving benefits for the patient. However, this procedure involves relatively high radiation dose. The purpose of this study was to determine the average effective dose of patients undergoing coronary angiography and to estimate the associated radiation risk in terms of fatal malignancy. *Materials and Methods:* Radiation doses received by 103 patients who underwent coronary angiography (CA) at one hospital of Yazd province in Iran were measured in terms of Kerma Area Product (KAP). KAP values were then used to determine the effective dose and the organ doses using the NRPB-S262 conversion factors and to estimate the radiation cancer risk based on the population averaged probability coefficients given in ICRP-60 and BEIR-VII report. *Results:* A mean KAP value was found to be 29.15 ± 16.97Gy.cm$^2$ and the estimated mean values of effective dose was 5.0 ± 3.18mSv. The dose of lung, esophagus, bone marrow, skin, stomach and female breast were 24.99±14.93 mSv, 14.01±9.47 mSv, 3.72±2.61 mSv, 2.9±1.8 mSv, 2.17±1.62 mSv and 1.46±0.32 mSv, respectively. The estimated total annual collective dose and caput dose were 17.52 man-Sv and 0.018mSv respectively. The frequency of examinations per 1000 population in Yazd was 3.5 which is lower than UK and the health care level I countries. Taking into account the ICRP risk factors, radiation dose arising from CA examinations could lead to 239 fatal cancers per million cases. *Conclusion:* Although the mean values of effective dose found in this study was lower than most of the published results, however CA examinations should be justified. **Iran. J. Radiat. Res., 2010; 8 (3): 161-167**

***Keywords:*** *Coronary angiography, Kerma-area product, effective dose, radiation risk.*

## INTRODUCTION

The increasing frequency of angiography and interventional radiology procedures in the recent years in Yazd city in Iran raised the radiation exposure of the population. These examinations are characterized by extended fluoroscopy times and they require many radiographic images to be taken from areas of interest in body. Consequently, the X-ray doses to patients are expected to be relatively high and stochastic effects have to be considered (1). Effective dose is considered the most appropriate quantity for estimating the stochastic risk of exposure to ionizing radiation (2). The radiation dose depends on a number of factors, including patient size, equipment, technique and type of examination. Large variation in patient dose has been demonstrated in several studies (3). Some of the parameters affecting CA dose are: tube voltage, anode current, tube filtration, cineradiography frame rate, dose per frame, entrance dose rate, image intensifier field size and collimation, beam angulations, number of views, fluoroscopy time, image resolution, interventional cardiologists experience, lesion type and patient expansion (4). Some of these parameters have been discussed in our last report (5). In this study the effective doses of CA procedures was assessed for estimation of cancer risk-related and was continue of our recent studies that evaluated risk of general X-ray and CT examinations in Yazd province (6, 7). An estimation of the effective dose can be obtained from measurements of KAP (2). There are many publications for estimation of effective dose in interventional radiology procedures where KAP and exposure factor data are available (7-9). The National Radiological Protection Board (NRPB) has published conversion factors for both KAP and entrance surface dose (ESD)

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measurements for 68 common radiographic projections and 9 complete X-ray examinations [10]. KAP measurement is a valuable and convenient method for dose assessment, especially for dynamic procedures, such as CA and percutaneous transluminal coronary angioplasty (PTCA), in which beam direction and exposure parameters continuously vary. In the present study, the information of radiation doses of 103 patients who underwent CA at one Yazd hospital were used for assessing the average effective dose, average doses of various organs and estimation of the associated radiation risk in terms of fatal malignancy.

## MATERIALS AND METHODS

4676 coronary angiography procedures were performed between 2008 -2009 at two Yazd hospitals. The population of Yazd province in year 2007 was 988440 people. KAP measurements were made on 103 coronary angiographies, (59 male and 44 female patients, about 70% patients age were from 40 to 60 years) performed at one Yazd hospital. In our previous study we found no significant difference between the mean KAPs due to CA examinations at the two Yazd hospitals [5]. The examinations were performed using a Siemens system (AXIOM Artis model, Germany) with an over couch flat panel detector that was installed in 2008. One cine mode (25 frames/s) and a fix field of view (25cm) were routinely used for all the patients. The potential for cineangiography was in the range of 65 to 102 kV. The total filtration varies automatically considerably depending on the imaging mode selected having values between 2 and 3.5 mmAl so with increase add filter the patient KAP was decreased. Patient radiation dose was measured by a calibrated KAP meter (PTW, Diamentor, Freiberg Germany) attached on the head of X-ray tube. Patient data collected were: name, age, sex, weight and height. Technical data collected were: potential, field size, total filter, cine frames, fluoro time, beam direction and corresponding KAP for each projection. Required data for calculation of effective dose in each of two beam directions right anterior oblique (RAO) and left anterior oblique (LAO) automatically was recorded by angiography system. For using NRPB-S262 tables which converted KAP to effective dose we needed to upper data for each direction individually. The mean potential and mean total filter for each of two projections RAO and LAO were calculated. There are publications that enable hospitals to estimate effective dose (E) for interventional radiology procedures where KAP and exposure factor data are available. The National Radiological Protection Board (NRPB) has published conversion factors for both KAP and entrance surface dose (ESD) measurements for 68 common radiographic projections and 9 complete X- ray examinations [10]. The FDA also has published a handbook containing data from which absorbed dose in selected tissues can be estimated for fluoroscopic and cineangiographic examinations of the coronary arteries of adults [11]. Effective dose values, resulting from the two methods proposed by NRPB and FDA, are compared by Lobotessi *et al.* and found no statistical difference between two methods [8]. In this study for each CA examination, patient effective dose and organ doses were estimated based on NRPB-R262 conversion coefficients [10]. The appropriate conversion coefficient for each potential value and total filter was determined using interpolation. This study was restricted to patients in the weight range of 71 ±12 kg so use of the NRPB-R262 conversion factors which are based on average body weight of 70 kg are suitable. Lung, skin, stomach, bone marrow and esophagus organs were selected for assessing organ dose. The breast organ was included only for female patients. The accuracy of the generator kVp was verified during installation procedure with the cooperation of Siemens engineers (<3% error). The potential risk of malignancy was determined by applying the nominal fatality probability coefficients given by the current report international commission of radiation protection, ICRP-60 and BEIR VII to the effective dose determined by NRPB-R262 (11, 10).

## RESULTS

The patient sample consisted of 103 patients with average weight 71±12, 57% of which were male and 43% were female patients. The average age of patients was 57±12 years. A statistical analysis of results in the coronary angiography examinations is given in table 1. This table presents fluoroscopy time, total tube filter, number frames, total KAP of cine and fluoroscopy modes, tube voltage and anode current resulting from the RAO and LAO projections. These projections contain various angels zero to 90 degrees in cranial and caudal angulations. Intermediately 40% of exposure direction was in RAO and 60% in LAO with various angels. All of these data automatically were recorded by the angiography system. Some of these data were used in calculation of effective dose by NRPB-R262. 4676 CA procedures were performed by two angiography units of the Yazd hospitals in one year (2007-2008). Based on the reception information of cardiac center about 25% of these patients were referred from the neighbor Yazd provinces, so only 4676×0.75 = 3507 of these patients were from Yazd city. The collective dose of this population was 3507 ×5.0 = 17.53 person-Sv (average effective dose result of CA is 5.0 mSv) and caput dose of Yazd province with population 988440 person was 0.018 mSv. This data and number of CA examinations per year and per person were compared with the other studies (table 2). Table 3 shows the average radiation doses ±1SD of the various organs moreover effective dose due to the CA procedures. The results suggest lungs and esophagus doses are more than the breast, skin, stomach and bone marrow doses. Lungs and esophagus are organs which absorbed the most equivalent dose 25±15 mSv and 14±9.5 mSv respectively, so based on current ICRP-60 report, their fatal cancer risk are 156 and 35 per million cases respectively (table 3).

The frequency distribution of patient effective dose was in the range of 1mSv to 15 mSv and is shown in figure 1. Total patient samples were 103 and maximum frequency was in the range of 4-5 mSv effective doses. In table 4, the sample size, total KAP, fluoroscopy time, frame cine number and effective dose of this survey were compared with the literature. The mean effective dose due to CA examinations

Table1. Radiation exposure parameters of two projections RAO and LAO in coronary angiography examinations, these two projections contain various angels zero to 90 degrees in cranial and caudal angulations. Values are presented as Mean ±1SD.

| projection | % Share in image | Tube voltage (cine) (kV) | Cine frames | Anode current (cine) (mA) | Fluoro time (min) | Filtration (mmAl) | Total KAP ($Gy.cm^2$) |
|---|---|---|---|---|---|---|---|
| RAO | 40 | 73.7±5.8 | 226±119 | 2588±1176 | 1.08±0.95 | 2.7±0.5 | 12.01±10.7 |
| LAO | 60 | 78±7.7 | 235±135 | 2903±1345 | 1.62±1.4 | 2.4±0.4 | 17.1±11.2 |

Table 2. Comparison of effective dose, number of examination per year and per people, collective dose, and caput dose due to CA procedures of Yazd province with other studies in the literature is presented. Values are presented as Mean ±1SD.

| Studies | Effective dose (mSv) | Exams per year (×1000) | Population[1] (×1000) | Collective effective dose (man-Sv) | Caput dose (mSv) | Exams per 1000 people |
|---|---|---|---|---|---|---|
| This study | 5.0±3.18 | 3.507 | 988 | 17.52 | 0.018 | 3.5 |
| Broadhead *et al.* (14) | 7.44 | 4.628 | 2927 | 34.4 | 0.01 | 1.58 |
| Hart and Wall (23) | 6.6 | 159 | 59000 | 1050 | 0.018 | 2.7 |
| Borretzen *et al.* (21) | 8.9 | 58 | 4550 | 516 | 0.11 | 13.1 |
| Brugmans *et al.* (22) | 4.8 | 84.5 | 15648 | 405 | 0.026 | 5.4 |

in this study is lower than the all results except of Leung results p<0.00) (1, 3, 8, 13, 14).

## DISCUSSION

Use of ionization radiation for medical examinations is the largest manmade source of exposure (24). Interventional procedures are only 2% of all radiological procedures, but contribute to about 20% of the total collective dose per head per year in Germany (25). On average, a coronary angiography corresponds to a radiation exposure for the patient of about 300 chests X-rays (26).

Invasive cardiology procedures increased in the recent years but it has been accompanied by concern for the safety of the staff. Interventional cardiologists have an exposure per-head per year very higher than that of radiologists (11-27). A reduction of occupational doses can be achieved by intensive training program. The awareness of radiation effects may be suboptimal in the

Table 3. Mean organ doses (mSv) and mean effective dose (mSv) of the 103 CA examinations and also cancer risk of some organs. Values presented as mean ±1SD.

| Organ | Lungs | Esophagus | Bone marrow | Skin | Stomach | Breast | Effective dose |
|---|---|---|---|---|---|---|---|
| Dose (mSv) | 25±15 | 14±9.5 | 3.7±2.6 | 2.9±1.8 | 2.1±1.6 | 1.4±.3 | 5.0±3.18 |
| fatal cancer risk per million case (current ICRP 60) (29) | 156 | 35 | 1.2 | 0.6 | 9.8 | 2 | 239 |
| Risk of fatal cancer per million case (BEIR VII) (29) | 304 | 18 | 1.2 | 0.6 | 16.7 | 4.6 | 237 |

Table 4. Comparison of dosimetric data (mean values) in CA exams in this study and the some references.

| Author | Sample size | KAP[1]cine + fluoro ($Gy.cm^2$) | Fluoroscopy Time (min) | Cine frame number | Effective dose (mSv) |
|---|---|---|---|---|---|
| This study | 103 | 29.14±16.9 | 2.71±2.3 | 462±197 | 5.0±3.18 |
| Lobotessi (8) | 18 | 58.3 | 8.9 | 1597 | 12.9 |
| Leung (13) | 90 | 14 | 3.1 | 639 | 3.1 |
| Broadhead (14) | 2174 | 57.8 | 5.7 | 689 | 7.44 |
| Bahreyni (1) | 116 | 32.47 | 3.4 | -- | 6.75±0.85 |
| Padovani (3) | 672 | 45 | 6.5 | 700 | 8 |

[1] Values presented as Mean ±1SD

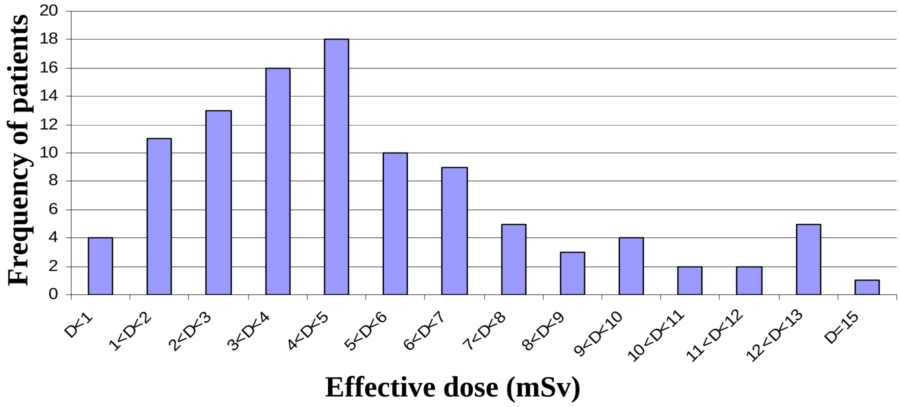


Figure 1. Frequency distribution of the patient's effective dose due to CA examinations (total patients was 103).

medical community. It is recommended by professional guidelines that the responsibility of all physicians is to minimize the radiation injury hazard to their patients, to their professional staff and to themselves [26]. In Yazd province 3507 coronary angiography was achieved by two angiography systems in one year (2007-2008) which corresponds to 1.1% of the all conventional radiology and CT examinations (327170) per year (2005-2006), but the collective effective dose of CA examinations was 17.52 man-Sv which is 27.5% of the collective effective dose due to conventional radiology and CT examinations (63.64 man-Sv) [6,7]. On average, a coronary angiography corresponds to a radiation exposure for the patient of about 110 chests X-rays [7]. Fluoroscopy time, frame number, anode current, tube voltage in cine mode and total KAP present a wide range of values due to the variety of examination protocols, complexity of patient case and the cardiologist's experience. The imaging system (Siemens, flat panel detector), used in this study has been set up to maintain about 75 kVp to optimize the iodine contrast. The automatic $kV_p$ and added filter control for both cine and fluoro mode produce qualify image together low patient dose. The average fluoroscopy time per case was also low; this reflects the emphasis placed on minimizing screening time.

Relation of KAP to lung and esophagus dose in LAO and RAO projections of CA base on NRPB-R262 conversion coefficients is high value of 0.8. Therefore these two organs are target organs in right and left anterior oblique directions of exposure during CA examinations and absorbed maximum radiation.

The mean effective dose of this study (5±3.18mSv) is lower than the results of Broadhead *et al.* [14], Hart and Wall [23], Borretzen *et al.* [21], Lobotessi *et al.* [8], Padovni *et al.* [3], Bahreyni *et al.* [1] (P<0.00) and hasn't significantly different from the results of Brugmans *et al.*[22], and Leung and Martin [13]. Comparison SENTINEL RLs[3] of effective dose (8 mSv), Fluoro-time (6.5min) and number of cine image (700) in CA examinations with analogue parameters of this study results which are 5 mSv, 2.7 min and 461 number respectively, our data is significantly lower than SENTINEL RLs (p<0.00) [3]. So optimization in CA examinations conditions for ALARA regard is suitable [1, 3, 8, 13,14].

With increase twofold in CA examinations frequency each 5 years base on reports of Broadhead *et al.* [14], Hart and Wall [23], and Borretzen *et al.* [21], CA frequency was about 10 exam per 1000 person in 2007 year in European countries so number of CA examinations in Yazd province is lower than these countries therefore performing these exams may be justified. Fatal malignancy risk due to CA examinations were estimated 237 and 239 per million cases respectively base on current ICRP-60 and BEIR VII estimation [29]. Base on Iranian annual of national cancer registration report of 2006 year [30], cancer new case in Yazd province with 988440 populations was 1180. Base on BEIR VII report, new fatal cancer case due to the collective dose of CA examinations that were achieved in one year in Yazd was 0.84 person [29], whereas this risk factor due to convetional radiology and CT examinations was 1.55 and 1.62 person respectively [6, 7]. Therefore approximately 4 new fatal cancer cases per year were due to performance of these three kind examinations in Yazd province.

The organ with the highest malignancy risk due to CA examinations is lung because of the high radiation dose received by this radio-sensitive tissue. The average lung dose from CA procedure was 25 ± 15 mSv in this study whereas the average lung dose from Harrison report and the Finnish study were 14.8 mSv and 58.7 mSv respectively, so lung dose of our results is higher than the Harrison report and lower than the Finnish study (P<0.00) (27). Our results showed fatal lung cancer base on current ICRP-60 and BEIR VII estimation were 156 and 304 per million cases [29].

## CONCLUSION

Low value of patient effective dose due to CA examinations at Yazd hospitals was showed these examinations were performed in optimum conditions. Low value of caput dose due to CA examinations showed justification was regarded too, if indication malady was regarded, so performance of these examinations were in acceptable conditions at Yazd hospitals.

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