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Evaluation of occupational radiation exposure of cardiologists in interventional radiography in Mashhad CATHLABs

Reza Fardid

Department of Radiology,
School of Paramedical Sciences,
Shiraz University of Medical Sciences,
Shiraz, Iran
Email: rfardid@gmail.com

Mohammad Taghi Bahreyni Toossi*

Medical Physics Research Center,
Faculty of Medicine,
Mashhad University of Medical Sciences,
Mashhad, Iran
Email: bahreynimt@mums.ac.ir
*Corresponding author

Mohammad Mehrpouyan

Nutrition and Biochemistry Department,
Faculty of Medicine,
Sabzevar University of Medical Sciences,
Sabzevar, Iran
Email: mohamad.mehrpoyan@gmail.com

Mahdi Ghorbani

Medical Physics Department,
Mashhad University of Medical Sciences,
Mashhad, Iran
Email: mhdghorbani@gmail.com

Abstract: Several studies have revealed that interventional radiography procedures performed in cardiology departments are high dose techniques. In this study, effective dose of cardiologists working in hospitals Catheterisation Laboratories (CATHLABs) in Mashhad city have been measured during Coronary Angiography (CA) and Percutaneous Transluminal Coronary Angioplasty (PTCA) procedures. In order to measure the dose per procedure and to estimate monthly effective dose of cardiologists, Electronic Personal Dosimeters (EPDs) were worn by 33 cardiologists over the apron on the collar. Mean effective dose of cardiologists per procedure was equal to 2.7 μSv

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(range: 0.3–14.3 μSv) for CA and 6.4 μSv (range: 1.3–27.5 μSv) for PTCA procedures. Mean monthly effective dose in cardiologists was equal to 158.3 μSv (range: 8.3–1050 μSv). According to the data obtained in this study the effective dose estimated for all cardiologists was lower than the monthly limits recommended by International Commission on Radiological Protection (ICRP).

Keywords: staff dose; interventional radiography; occupational exposure; effective dose.

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Biographical notes: Reza Fardid is an Assistant Professor at Shiraz University of Medical Sciences, Iran. He obtained his BSc in Physics (Laser) from Shiraz University and MSc in Medical Physics from Tehran University of Medical Sciences. He did his PhD in Medical Physics from Mashhad University of Medical Sciences. He was an Advisor to some MSc student projects during his PhD programme period. He has published some scientific articles, abstracts and presented some poster presentations at international conferences.

Mohammad Taghi Bahreyni Toossi is Professor and Director of Medical Research Center at Mashhad University of Medical Physics Sciences. He did BSc in Physics from Iran and MSc in Radiation and Environmental protection, and PhD in Medical Physics from UK. He is president of the Iranian Board of Medical Physics Since 1996. He has been an advisor to many MSc and PhD students and has published over 100 scientific papers, and presented more than 50 oral and poster presentations at international conferences. He is co-author of two books written in Persian (Medical Physics and Computed Tomography) and co-translator of a book on radiation protection.

Mohammad Mehrpouyan is an Academic member of Nutrition and Biochemistry Department at Sabzevar Universiy of Medical Sciences. He obtained his BSc in Physics (Solid State Physics) from Birjand University, and his MSc in Medical Physics from Mashhad University of Medical Sciences.

Mahdi Ghorbani is Assistant Professor of Mashhad University of Medical Sciences, Mashhad, Iran. He obtained his BSc in Physics from Iran, MSc in Medical Physics from Ahvaz Jundishapur University of Medical Sciences, and PhD in Medical Physics from Mashhad University of Medical Sciences.

1 Introduction

It has been widely reported that occupational exposure from interventional diagnostic radiology is high, and nowadays this is a cause of concern from health physics point of view (Kuipers et al., 2010). Several studies have revealed that interventional fluoroscopy procedures performed in cardiology departments are high dose techniques. In addition to patients, cardiologists are also susceptible to receive high radiation dose (Martin, 2009). Occupational dose of radiation workers is measured by different types of dosimeters, but it is mostly expressed in terms of personal dose equivalent (Hp(10)) that is measured in Sievert (Sv) (Martin, 2009; Kuipers et al., 2010). Effective dose estimation is an essential element of monitoring programme planned for occupationally exposed persons.

Development of technology has brought about advancements in design and making of fluoroscopy and angiography devices which have resulted in lowering the level of radiation dose to cardiologists and patients; at the same time, it has also improved the quality of imaging (Martin, 2009).

It is common that the personnel of hospitals' CATHLAB put on lead apron in order to protect themselves from radiation exposure. During all interventional procedures the cardiologists use wrap-around lead aprons (skirts and vests) with overall lead equivalence of 0.25 mm at 100 kVp. The emphasis is on the perfection of the shielding material rather than its thickness alone (Martin, 2009). Other protecting devices such as the protection layer under the patient's bed and lead safety goggles worn by cardiologists reduce the amount of scattered radiation.

Hp(10) which is measured by personal dosimeter is representing absorbed dose at 10 mm depth of soft tissue (Padovani et al., 2001). It is an estimate of effective dose (E) and several algorithms have been proposed to deduce actual effective dose from Hp(10). These algorithms have been utilised to conclude a more accurate value for E, arising from different circumstances. Schultz and Zoetelief (2006) reported that the ratio of Hp(10) to effective dose is more than one.

To estimate effective dose by a single dosimeter, International Commission on Radiological Protection (ICRP 85) and National Council on Radiation Protection and Measurements (NCRP 122) recommend using one dosimeter under or above the lead apron (Clerinx et al., 2008; Martin, 2009), the dosimeter worn above the lead apron will highly overestimate effective dose, and vice versa. Therefore ICRP recommends double dosimetry method in which two dosimeters are used: one, over the apron on the neck, and the other under the apron on the chest regions (Clerinx et al., 2008). If two dosimeters are used, NCRP 122 recommends that one dosimeter should be placed above the apron on the neck and the other under the apron on the waist regions (NCRP-122, 1995; Clerinx et al., 2008).

Effective dose is measured from Hp(10) which is read from single or double dosimetry method and various algorithms have been employed by different researchers in this field. Many researchers have studied different algorithms to estimate the effective dose from a single dosimeter over or under the lead apron. In other words, some researchers have applied double dosimetry method and some have used single dosimetry method (Järvinen et al., 2008a; Kuiper et al., 2008). Järvinen has suggested that Von Boetticher formula be used for the double dosimetry method and the NCRP formula for the single dosimetry method (Rosenstein et al., 1994; Järvinen et al., 2008b). In another report, they thoroughly examined different algorithms to derive the effective dose from Hp(10) measurements and compared the related conversion coefficients (Järvinen et al., 2008a). Padovani re-examined several algorithms and conversion coefficients which are used to estimate effective dose from single and double dosimetry method (Padovani et al., 2001). Recently, a radiation protection centre in Netherlands (Nuclear Regulatory Commission) has recommended workers who used lead apron to use a single dosimeter over the apron, then divide the dosimeter reading Hp(10) by 5 to estimate E (Kuipers and Velders, 2009).

The significance of monitoring of radiation workers, in particular those who are working in interventional radiological centres, it seems that, using active dosimeters can be helpful in easy monitoring. Therefore, in this study, measurements were made using an electronic personal dosimeter and applying the single dosimetry algorithm to estimate effective dose of cardiologists in CATHLABs.

2 Materials and methods

Thirty three cardiologists who practised angiography and angioplasty procedures between March 2010 and September 2010 in hospital CATHLABs of Mashhad city were asked to wear one electronic personal dosimetry, EPD (MINI 6100, England) over the apron. They performed 300 procedures (175 CAs and 125 PTCAs) over a period of six months. 300 samples of dose over the protective apron on collar region were measured. Each cardiologist was given an identification number and the results of measurements per procedure were recorded. The average number of cardiac interventions performed by one cardiologist during the study period was equal to nine procedures. The lowest measurable dose with the EPD used in this study was 0.1 μSv. The lowest energy detection threshold of EPD was 30 keV.

Electronic Personal Dosimetry (EPD) devices are very light and easy to use (Johnson et al., 2001; Tsapaki et al., 2004). These devices are capable to measure equivalent dose in 10 mm of soft tissue, Hp (10). Instant and cumulative dose measurements as well as various dose levels alarming are other functions of these dosimeters. Hence, they are suitable devices for CATHLAB personnel monitoring (Prlic et al., 2008). The electronic devices in this study were calibrated by the SSDL (Secondary Standard Dosimetry Laboratory) of Atomic Energy Organization of Iran. Based on NCRP Report 122 recommendations (NCRP-122, 1995), dosimeters were worn over the apron on neck and the dose Hp(10) values were read and recorded following to each procedure. Effective doses were estimated from the Hp(10) values by Huyskens's algorithm (S_2) which are shown in Table 1. In this table, S_1, S_2 and S_3 are attributed to those algorithms in which a single dosimeter is used over the apron on collar region.

Table 1 Various equations to convert dosimeter readings Hp(10) to effective dose of cardiologists obtained from single dosimetry

Algorithm's name	*Reference*	*Conversion formula (algorithm)*
S_1	(Järvinen et al., 2008a; NCRP, 1995)	$E(S_1) = H_p(10)_{\text{Neck, Over}} \times \frac{1}{21}$
S_2	(Huyskens et al., 1994; Kuipers and Velders, 2009)	$E(S_2) = H_p(10)_{\text{Neck, Over}} \times \frac{1}{5}$
S_3	(Padovani et al., 2001)	$E(S_3) = H_p(10)_{\text{Neck, Over}} \times \frac{1}{33}$

Since thyroid is a radiosensitive organ, there are some CATHLABs in which thyroid shield is used for additional protection of this organ. When thyroid shield is used, the measured Hp(10) by the dosimeters placed over apron cannot be a true estimate of the effective dose, because thyroid receives a lower dose when compared with the case in which thyroid shield is not used. Hence, to conclude effective dose from measured Hp(10) different formula should be used whether thyroid shield is used or not (Rosenstein et al., 1994; Clerinx et al., 2008; Järvinen et al., 2008a; Järvinen et al., 2008b; Kuipers and Velders, 2009). Since in the present study the cardiologists wore thyroid shield, from the previous reported formulas we have adopted the equation which satisfies the use thyroid shield (Foti et al., 2008; Vaño et al., 2006; Rosenstein et al., 1994; Clerinx et al., 2008; Järvinen et al., 2008a; Järvinen et al., 2008b; Kuipers and Velders, 2009).

In this work, the tube's energy was ranging between 60 and 120 kVp depending on the tube position and thickness of the examined part of the body to obtain the best image (Bahreyni Toossi et al., 2008). Average number of CA and PTCA procedures performed monthly by cardiologists was also calculated from the obtained data. The average number of monthly procedures performed by individual cardiologists were also recorded and finally utilised to determine the monthly effective dose of individual cardiologist.

3 Results

Mean and standard deviation of Hp(10) per procedure of cardiologists who performed 175 CA and 125 PTCA are presented in Figures 1 and 2, respectively. The Hp(10) values were measured over apron on collar region. All cardiologists performed CA and only eight cardiologists CA and PTCA.

Over apron average equivalent dose, Hp(10), per procedure for all cardiologists arising from CA and PTCA was 13.0 μSv (range: 1.7–71.4 μSv) and 32.1 μSv (range: 6.4–137.6 μSv), respectively.

Figure 1 Results of mean personal equivalent dose, Hp(10), of cardiologists per CA procedure (μSv/procedure) measured over the apron (on collar) (see online version for colours)

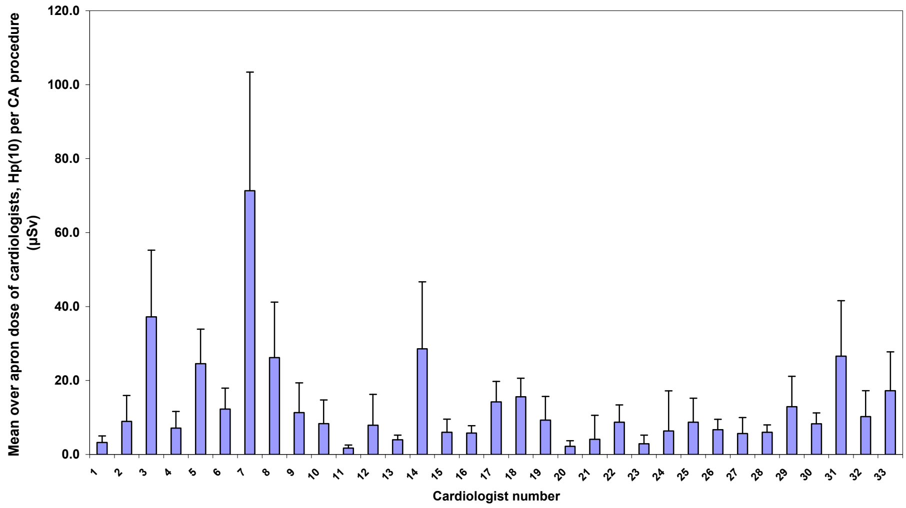


Figure 2 Results of mean personal equivalent dose, Hp(10), of cardiologists per PTCA procedure (μSv/procedure) measured over the apron (on collar) (see online version for colours)

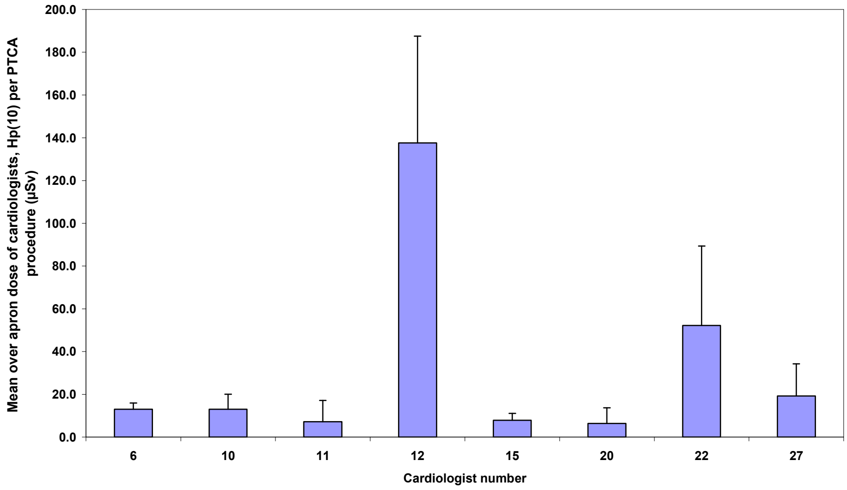
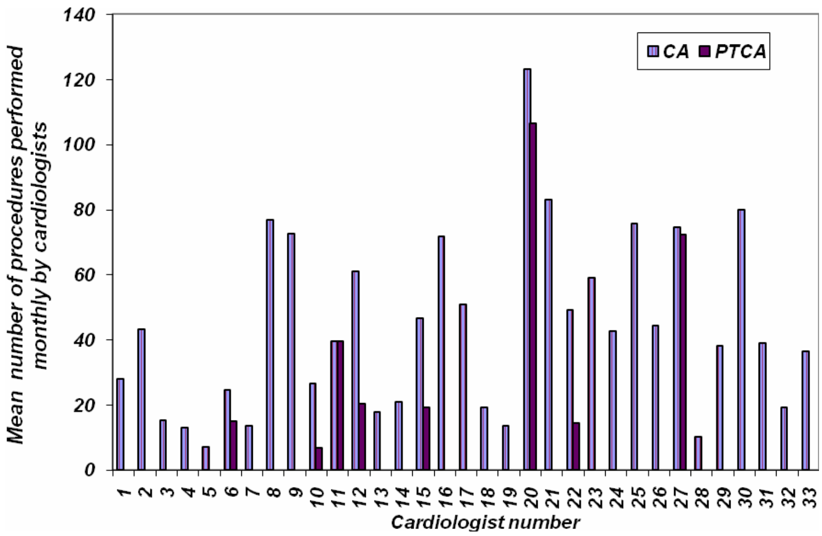


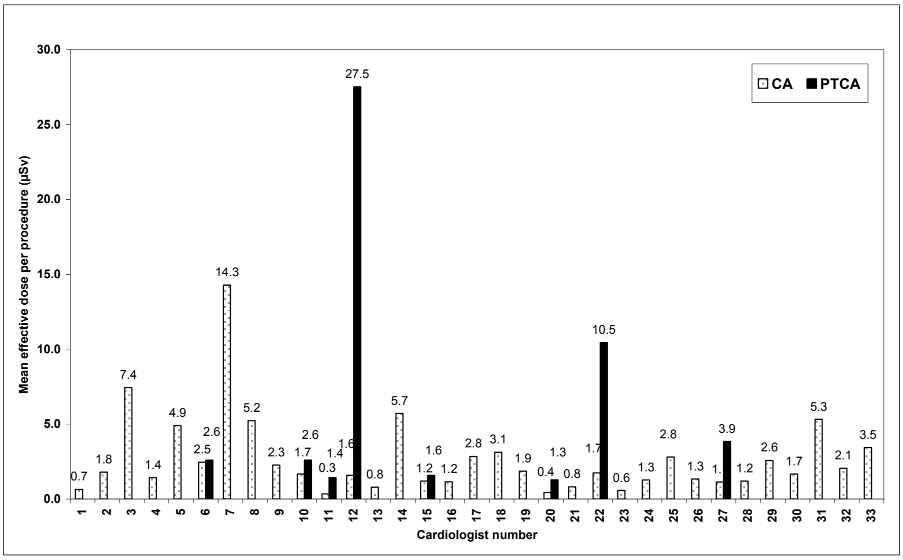
Figure 3 shows average number of angiography and angioplasty procedures performed monthly by individual cardiologist in hospitals of Mashhad city.

Figure 3 Mean number of CA and PTCA procedures performed monthly by cardiologists in Mashhad CATHLABs (see online version for colours)



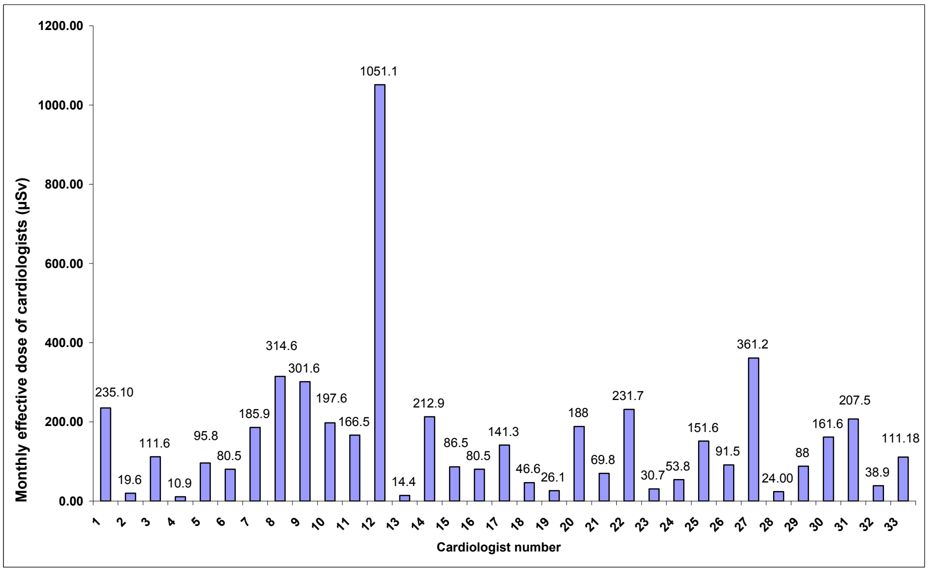
Mean effective doses of cardiologists per CA and PTCA procedures that were estimated by S_2 algorithm (Huyskens's algorithm) are presented in Figure 4. Mean effective dose of cardiologists per procedure was equal to 2.7 μSv (range: 0.3–14.3 μSv) for CA and 6.4 μSv (range: 1.3–27.5 μSv) for PTCA procedures. Mean monthly effective dose of cardiologists was equal to 158.3 μSv (range: 8.3–1050 μSv).

Figure 4 The mean effective dose per procedure (μSv/procedure) to cardiologists during CA and PTCA procedures performed in Mashhad CATHLABs



Monthly statistics of procedures performed by each cardiologist (as presented in Figure 3) and their mean effective dose per procedure (as presented in Figure 4) were employed to calculate their approximate monthly effective dose. The calculated monthly effective dose values are shown in Figure 5. Mean monthly effective dose of cardiologists is equal to 158.3 μSv (range: 8.3–1050 μSv).

Figure 5 The estimated monthly effective doses of cardiologists arising from interventional angiography procedures (CA and PTCA) performed in Mashhad CATHLABs as estimated from S_2 algorithm (see online version for colours)



4 Discussion

In this study EPDs were used to measure Hp(10) of a group of cardiologists performing CA and PTCA procedures in hospital CATHLABs of Mashhad city.

EPDs are efficient to provide the dose equivalent at the depth of 10 mm in soft tissue (Hp(10)). EPDs are small, easy to use and display instant dose measurements. The latter reduces the risk of missing accidental exposures, which are often being neglected. The characteristics and specifications of EPDs are in compliance with the requirements of a personal monitoring device intended for occupational exposures. Hence, EPDs are recommended for surveying radiation dose of workers and as an essential part for a radiation monitoring programme.

EPDs are less prone to error, easy to use and more cost effective, we have used single dosimetry algorithm to estimate effective dose from Hp(10) readings of the EPD. Based on the radiation protection philosophy overestimation of risks associated with radiation dose would lead us to a safer state. So, according to Table 1, it is shown that S_2 algorithm is more accurate in comparison to other single dosimetry algorithms.

As described in the results section, S_2 algorithm was used to estimate monthly effective dose. Using this algorithm leads to values higher than those obtained by the other algorithms (S_1 and S_3). This fact indicates that the S_2 algorithm incorporates less underestimation in assessment of effective dose. This may be considered as a conservative approach, however would result in lower risk of stochastic effects. Based on the results acquired in this study (Figure 5), the effective dose of all cardiologists is lower than the recommended ICRP monthly limit of 1.66 mSv for radiation workers. Finally, according to our results, due to the ease of use and real-time functionality of the EPDs they can be used for CATHLAB staff monitoring.

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