Atom Indonesia Vol. 45 No. 1 (2019) 37 - 41

Atom Indonesia

Journal homepage: http://aij.batan.go.id

Occupational and Patient Doses in Interventional Cardiology in Indonesia: A Preliminary Result

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ARTICLE INFO

Article history:
Received 06 June 2018
Received in revised form 12 December 2018
Accepted 12 December 2018

Keywords:
Occupational exposure
Patient exposure
Interventional cardiology
Medical exposure

ABSTRACT

Interventional cardiology is a branch of cardiology that manages the catheter based treatment of structural heart illnesses. These minimally invasive procedures involve inserting catheters and other devices through superficial arterial and venous access sites. Due to increased reliability and advancing technology, the number and complexity of interventional cardiology procedures haves increased in recent years. The increasing complexity of the procedures, however, require longer fluoroscopic duration, leading to increased exposure time to ionizing radiation for the patient and also for the medical staff since they need to remain close to the patient throughout the procedure. This study attempts to investigate the occupational and patient doses during the course of several interventional cardiology procedures in Indonesia, i.e. CA, PCI, cathscan, PA, PTCA, TACE, PAC and peripheral vascular. Occupational doses were measured by using individually packed three chips of TLD-100 placed in over- and under-thyroid shield used by medical staff, over- and under-apron in waist position, inside a special 'eye-D' holder, and inside a ring holder, while patient doses were estimated by using individually packed three TLD-100 chips attached in the x-ray tube. All TLDs were calibrated in the Secondary Standard Dosimetry Laboratory (SSDL) Jakarta. The study was performed in three big hospitals in the cities of Jakarta, Yogyakarta and Semarang. The results show that PCI procedure was the most performed one during the course of this study and gave the highest radiation doses to the staff for all type of doses calculated and measured. The maximum effective doses, eye lens doses, extremity doses, thyroid doses and gonad/ovary doses were 0.098 mSv, 0.1967 mSv, 0.7604 mSv, 0.1760 mSv and 0.0990 mSv, respectively. In the case of patient doses, the mean value of DAP for PTCA procedure of 776.76 Gy cm^2 was the highest compared with those for other procedures. The results of measurement for occupational doses were in general similar to those reported by other authors, but not for patient doses that was found to be 4-5 times higher. Due to the involving of various parameters during the course of interventional cardiology procedures, it was difficult to establish a correlation between the doses received by medical staff and by the patients.

INTRODUCTION

Medical use of ionizing radiation is known to be the main source of man-made doses to the world's population. As cited by Leyton, *et al*. [1], the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) stated that interventional cardiology procedures represent the third largest contribution to the collective dose (i.e. the total dose incurred by a population) after computed tomography and nuclear medicine.

Interventional cardiology is a branch of cardiology that manages the catheter based treatment of structural heart illnesses. The procedure has the advantage of avoiding scars and pain, which are always suffered by patients if done surgically.

These minimally invasive procedures involve inserting catheters and other devices through superficial arterial and venous access sites.

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DOI: https://doi.org/10.17146/aij.2019.862

Most common imaging equipment used for this purpose is X-ray fluoroscopy with possibility of changing projections without moving the patient (C-arm) and production of high- quality image series (cine mode).

Due to increased reliability and advancing technology, the number and complexity of interventional cardiology procedures haves increased in recent years. The spectrum of interventional cardiology activities are now broadened into procedures in coronary, valvular and congenital diseases [1].

In Poland, 208842 coronary angiography (CA) and 113928 percutaneous coronary intervention (PCI) procedures were performed in 2012 [2]. An increase of 34 % from 2004 to 2013 (36810 procedures) in diagnostic catheterization procedures was recorded in Portugal, with a rate of 3529 CA per million population [3]. Gudnason *et.al.* [4] compared interventional cardiology performed in two European countries, and found that the rate of CA per million inhabitants was higher in Iceland than in Sweden.

The increasing complexity of interventional cardiology procedures, however, require longer fluoroscopic duration, leading to increased exposure time to ionizing radiation for the patient, and also for the medical staff since they need to remain close to the patient throughout the procedure. The scattered radiation from the patient and from elements of the X-ray equipment is the main sources of exposure to the medical staff that received via unshielded parts of their bodies [5].

The increasing exposure time will undoubtedly increase the risk of health effects to the patient as well as to the medical staff. The health effects of exposure may be deterministic in nature (e.g. radiodermatitis, temporary sterility and cataract), or stochastic ones (e.g. cancer and hereditary diseases).

Radiation doses received by patients and medical staff have been widely measured [6-8]. Recent study suggests possibility of radiation-induced cataract for medical staff in interventional cardiology [9]. The estimation of staff lens doses in three interventional procedures suggest that more than 800 procedures per year and per operator were necessary to reach the lens dose limit [10], and the elevated opacity risks have been shown in interventional cardiologist's personnel who often have substantial doses to the lens of the eye [11].

In the present study, radiation doses received by the patients and medical staff in interventional cardiology in three hospitals in Indonesia were examined. The purpose was to find out the extent of those doses, and compared them with those published internationally.

EXPERIMENTAL METHODS

The measurements of patient and occupational doses were performed at the cardiac catheterization laboratory in three hospitals in the city of Jakarta, Yogyakarta and Semarang in Indonesia during the year of 2016. A total of 26 interventional cardiology patients and 45 medical staff, consists of 20 cardiologists, 19 nurses and 6 radiographers, involved in this study.

Patient doses in this study were not directly measured, but obtained from in-situ measurements performed by ionization chamber placed beyond the X-ray collimators. The results are displayed in the X-ray monitor.

Measurement of occupational doses was conducted according to the procedures described by Szumska [2] with slight modifications. In this case, measurements were realized by using an individually packed three chips of TLD-100 from Thermo Scientific Harshaw. All TLDs were calibrated in the Secondary Standard Dosimetry Laboratory (SSDL) Jakarta. The standard deviation of the TLD batch was of the order of 5 %, with the overall uncertainty was ≤ 20 % at the 95 % confidence level.

The arranged TLD chips were attached in over- and under-thyroid shield, under-apron in waist position, inside a special 'eye-D' holder, and inside a ring holder. TLDs placed under under-thyroid shield was used to estimate thyroid dose, while those placed under-apron in waist was used to estimate gonad/ovary dose, those placed in temple inside a special 'eye-D' holder was used to estimate lens eye dose, Hp(3), those placed in finger inside a ring holder was used to estimate extremity dose, Hp(0.07); and those placed over-thyroid shield and under-apron waist was used to estimate effective dose, E. Figure 1 shows the 'eye-D' holder and the ring holder used in this study.

Fig. 1. The 'eye-D' holder used to measure eye lens dose (left) and the ring holder to measure extremity dose (right).

The effective dose was calculated by using the following equation suggested by Niklason *et al*. [12]:

$$E = 0.02\ (H_{os} - H_u) + H_u$$

where H_{os} is the over-thyroid shield dose and H_u is the under-apron waist dose.

All TLDs were measured using Thermo Scientific Harshaw TLD reader model 3500. To obtain the true doses received by patients and workers, the results of the readout from TLDs were multiplied by correction factor obtained during calibration.

RESULTS AND DISCUSSION

Table 1 shows the occupational doses during interventional cardiology measured in this study. There were eight procedures conducted during the study, and two of them were performed with the radiographer only stood by in the control room and therefore their doses were not recorded. Those eight procedures were CA (coronary angiography), PCI (percutaneous coronary intervention), cathscan, PA (peripheral angioplasty), PTCA (percutaneous transluminal coronary angioplasty), TACE (transcatheter arterial chemoembolization), PAC (premature atrial contraction) and peripheral vascular.

As can be seen, PCI was the procedure attended by the most staff working in interventional cardiology in the three hospitals. This was understandable as Table 2 shows that PCI was the procedure most performed with 10 patients.

In general, PCI procedure also gave the highest radiation doses to the staff for all type of doses calculated and measured (i.e. effective dose, eye lens dose, extremity dose, thyroid dose and gonad/ovary dose). This was followed by the procedures of peripheral vascular, PA, PAC, TACE, cathscan, PTCA and CA.

For extremity doses [Hp(0.07)], the measured values for CA and PCI in this study were 93-93.5 μSv and 88.0-180.3 μSv. This can be compared with the range mean values measured by Szumska for CA and PCI procedures of 8-54 μSv and 6 - 93 μSv, respectively [2]. The higher range of occupational extremity doses from CA and PCI procedures measured in this study was thought due to no single filter applied in the ring holder used, so that all energies from X-ray beam entered and deposited in the TLD chip.

Domienik [13], however, reported that the maximum dose measured to fingers for CA and PCI procedures was 1.21 mSv, or 1210 μSv. This figure was quite higher than the highest measured dose of 180.3 μSv from this study.

In the case of eye dose, the measured from this study was ranged from 0.015 to 0.197 mSv, while the mean eye dose measured by several authors as reported by Szumska [2] ranged from 13 to 170 μSv, or 0.013 to 0.17 mSv. Results of this study were therefore slightly higher than that reported by Szumska, and this is no wonder since some factors exist during the study of eye lens doses measurement, e.g. type and complexity of the procedure undertaken, the skill and experience of the operators, the shielding equipment used, and the exposure settings [2].

Table 1. Occupational doses during interventional cardiology procedures.

Procedure	Type of staff	Number of staffs	Mean effective dose, E (mSv)	Mean eye lens dose, Hp(3) (mSv)	Mean extremity dose, Hp(0.07) (mSv)	Mean thyroid dose (mGy)	Mean gonad/ ovary dose (mGy)
CA	Cardiologist	2	0.0045	0.0150	0.0930	0.0225	0.0035
	Nurse	4	0.0092	0.0192	0.0935	0.0105	0.0087
PCI	Cardiologist	12	0.0654	0.1122	0.1803	0.0582	0.0688
	Nurse	11	0.0442	0.1001	0.0905	0.0460	0.0440
	Radiographer	8	0.0690	0.1075	0.0880	0.0478	0.0680
Cathscan	Cardiologist	2	0.0285	0.0280	0.2080	0.0370	0.0275
	Nurse	1	0.0270	0.0390	0.2630	0.0460	0.0250
PA	Cardiologist	3	0.0560	0.1967	0.2305	0.0483	0.0553
	Nurse	4	0.0417	0.0942	0.0943	0.0485	0.0775
	Radiographer	4	0.0397	0.0595	0.1250	0.0312	0.0397
PTCA	Cardiologist	1	0.0260	0.0700	0.3590	0.1760	0.0230
	Nurse	1	0.0980	0.1260	0.2140	0.0830	0.0990
TACE	Cardiologist	1	0.0397	0.0276	0.1523	0.0378	0.0394
	Nurse	1	0.0246	0.0190	0.0161	0.0130	0.0242
	Radiographer	1	0.0170	0.0754	0.0046	0.0430	0.0162
PAC	Cardiologist	8	0.0524	0.0889	0.1703	0.0428	0.0449
	Nurse	10	0.0402	0.0532	0.0811	0.0344	0.0378
	Radiographer	6	0.0407	0.0978	0.0756	0.0228	0.0308
Peripheral vascular	Cardiologist	1	0.0587	0.1327	0.7604	0.0417	0.0578
	Nurse	1	0.0483	0.0554	0.3718	0.0589	0.0477
	Radiographer	1	0.0124	0.0733	0.0586	0.0560	0.0132

For CA procedure, the eye lens doses from this study were 15 μSv for cardiologist and 19.2 μSv for nurse. Antic *et al.* [14], however, reported that the mean eye dose was 121 μSv for the first operator (i.e. cardiologist), 33 μSv for the second operator/nurse, and 0.16 μSv for radiographers. Compared to this study, it can be seen that eye lens dose measured were lower than that measured by Antic *et al*.

Haga *et al*. [15] measured the eye lens dose of the physician wearing and not wearing Pb glasses during CA procedures, and found that the eye doses for both conditions were 3.1 and 6.3 mSv, respectively. This showed that this study (0.015 mSv) measured a lower eye lens dose when it compared to the result of Haga without Pb glasses of 6.3 mSv.

The measurement of the eye lens dose received by medical staff was the most studied topic concerning the doses in interventional cardiology during the last 6 years. This was triggered by the statement of the International Commission on Radiological Protection (ICRP) that there is evidence suggesting the threshold dose for the lens of the eye which is considered to be 0.5 Gy, lower than previously considered [16].

Up until now, however, there is no standardized method for the measurement of the eye lens dose. The dosimeter types and their position around the eye are also varied. This study used individually packed three chips of TLD-100 in the 'eye-D' holder and placed near the left eye, whilst others used an array of 10 TLDs placed at the level of eye brows [13] and a TLD (DOSIRIS) placed in lateral to the left eye [15].

The patient doses during interventional cardiology measured in this study are shown in Table 2. The values of DAP and kerma were calculated by the in situ-calibrated dosimeters contained in the X-ray equipment.

Table 2. Patient dose during interventional cardiology procedures.

Procedure	No. of patient	DAP (Gy cm^2)	Kerma (mGy)	Range of fluoro time (min.)	Dose conversion coefficient (DCC) (mSv/Gy cm^2)
CA	2	113.53	226	1.44 – 2.59	1.24
PCI	10	195.50	1216.91	3.1 – 31.08	5.67
Cathscan	1	42.25	494	5.13	9.77
PA	4	9.61	74.36	4.44 – 14.80	10.75
PTCA	1	776.76	15778	118.4	6.82
TACE	1	58.94	369.00	19.5	8.75
PAC	6	41.73	565.00	2.6 – 12.2	18.55
Peripheral vascular	1	677.32	471.00	50.29	-

The dose-area product (DAP) is a quantity that represents the radiation energy transmitted to the patient during the procedure, expressed in Gy cm^2. This quantity can be used as an indicator of the patient's stochastic risk. DAP reflects not only the dose within the radiation field, but also the area of the tissue irradiated.

At present, kerma-air product (KAP) is also used to represent the radiation energy transmitted. DAP is actually KAP x (1-*g*), where *g* is the fraction of energy of liberated charged particles that is lost in radiative processes in the material. Since the value of *g* for interventional X-rays is only fraction of a percent, for all practical radiation protection purposes, DAP is then considered to be equal to KAP.

DAP for CA and PCI in this study were 113.53 Gy cm^2 and 195.50 Gy cm^2, respectively, while the study by Szumska [2] found the KAP for the same procedures were 22.7 and 43.1 Gy cm^2. This showed that results from this study are 4 - 5 times higher than that of Szumska. The same possible reasons for the disagreements in the results of eye dose measurements as mentioned before can be applied to these differences.

Considering the stochastic risk of radiation that might be experienced by patients undergoing interventional procedures, the risk can be estimated by applying the dose conversion coefficient (DCC), i.e. the effective dose normalized to a dosimetric quantity directly measurable [9]. This study provided calculated effective doses that can be related to the values of DAP that are provided by the X-ray equipment. Table 2 also shows the DCC that has been calculated by applying the measured dose normalized to the value of DAP.

Table 3 shows comparison of the values of DDC for CA and PCI procedures calculated by Hussein [7] and DDC for CA and PTCA procedures calculated by Ahmed [17], compared with those calculated in this study.

Table 3. Comparison of dose conversion coefficients (DCC) of this study compared with published data.

Procedure	Dose conversion coefficient (mSv/Gy cm^2)		
	Hussein [7]	Ahmed [16]	This study
CA	0.14	7.18	1.24
PCI	0.19	-	5.67
PTCA	-	7.41	6.82

As can be seen in Table 3, the DCC values are varied among authors. The DCC value for CA procedure obtained in this study was between the values calculated by Hussein [7] and Ahmed [16], while the DCC value for PCI procedure obtained in this study was higher than that of Hussein [7], but in case of PTCA procedure the DCC values of Ahmed [16] and of this study was quite similar. The variation of DCC values are also thought due to differences in some factors during the undergo of the procedure, as explained above.

Ideally, the amount of radiation doses received by medical staff should be correlated with the amount received by the patient represented by the value of DAP. However, the course of interventional cardiology procedures involving the great variation of parameters such as the skill of the staff, fluoroscopy time, proper selection of irradiation area, and technique to be used. It is, therefore, very difficult to obtain such a correlation in interventional procedures. This situation has also been raised by Szumska [2], who failed to establish the correlation due to the scattered results of measurement.

CONCLUSION

This study has shown that the PCI procedure was the most performed one during the course of this study, and gave the highest radiation doses to the staff for all type of doses calculated and measured. The results of measurement for occupational doses were found to be in general similar to those reported by other authors, but not for patient doses that was found to be 4 - 5 times higher. It was also difficult to establish a correlation between the doses received by medical staff and by the patients due to various parameters that involved during the course of interventional cardiology procedures.

ACKNOWLEDGMENT

We wish to thank the management and staff of the three hospitals in Jakarta, Yogyakarta and Semarang for granting permission to carry out the study in their respective hospital. The authors also acknowledge the help from Mmes Dyah D. Kusumawati, Helfi Yuliati and Suyati for preparing and reading the TLDs. This study was funded by the 2016 financial year research budget of the Indonesian government through PTKMR BATAN.

REFERENCES

1. F. Leyton, L. Canivaro, A. Dourado *et al.,* Rev. Bras. Cardiol. Invasiva **22** (2014) 87. doi: 10.1016/S2214-1235(15)30184-8.
2. A. Szumska, R. Kopeć and M. Budzanowski, Radiat. Meas. **84** (2016) 34. doi: 10.1016/j.radmeas.2015.11.003
3. H. Pereira, R.C. Teles, C. Marco *et al.,* Rev. Port. Cardiol**. 34** (2015) 673. doi: 10.1016/j.repc.2015.06.005.
4. T. Gudnason, G.S. Gudnadottir, B. Lagerqvist *et al.*, Int. J. Cardiol. **168** (2013) 1237. doi: 10.1016/j.ijcard.2012.11.054.
5. F. Leyton, M. Nogueira, J. Saad *et al.,* Radiat. Meas. **71** (2014) 349. doi: 10.1016/j.radmeas.2014.07.015
6. J.S. Wambani, G.K. Korir, M.A. Tries *et al.,* J. Appl. Clinical Med. Phys. **15** (2014) 262. doi: 10.1120/jacmp.v15i2.4555
7. E.H. Khalafalla and F.I. Habbani, Int. J. Sci. Res. **5** (2016) 2014. https:// www.ijsr.net/ archive/v5i3/NOV161030pdf
8. Z. Kallinikou, S.G. Puricel, N. Ryckx *et al.,* Am. J. Cardiol. **118** (2016) 188. doi: 10.1016/j.amjcard.2016.04.045.
9. R.A. Bitarafan, F. Noohi, H. Hashemi *et al.,* Res. Cardiovasc. Med. **4**(2015) 1. doi: 10.5812/cardiovascmed.25148.
10. E. Vano, R.M. Sanchez and J.M. Fernandez, Radiat. Prot. Dosim. **165** (2015) 279. doi: 10.1093/rpd/ncv049.
11. R.E. Shore, Mutat. Res. **770** (2016) 231. doi:10.1016/j.mrrev.2016.06.006
12. L.T. Niklason, M.V. Marx and H.P. Chan, Health Phys. **67** (1994) 611. https://journals.lww.com/health-physics/Abstract/1994/12000/The_Estimation_of_Occupational_Effective_Dose_in.3.aspx
13. J. Domienik, M. Brodecki and D. Rusicka, Radiat. Meas. **47** (2012) 130. doi: 10.1016/j.radmeas.2011.12.004
14. V. Antic, O. Ciraj-Bjelac, M. Rehani *et al.,* Radiat. Prot. Dosim. **154** (2013) 276. doi: 10.1093/rpd/ncs236
15. Y. Haga, K. Chida, Y. Kaga *et al.,* Sci. Rep. **7** (2017) 569. doi: 10.1038/s41598-017-00556
16. F.A. Stewart, A.V. Akleyev, M. Hauer-Jensen *et al.*, Ann. ICRP **41** (2012) 1. doi: 10.1016/j.icrp.2012.02.001.
17. N.A. Ahmed, S.B. Ibraheem and F. Habbani, Radiat. Prot. Dosim. **153** (2013) 425. https://doi.org/10.1093/rpd/ncs119