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Patient Radiation Doses in Interventional Cardiology Procedure

E. Hiswara*, D. Kartikasari, N. Nuraeni, H. Sofyan, K. Y. P. Sandy

Center for Technology of Radiation Metrology and Safety, National Nuclear Energy Agency (BATAN), Jl. Lebak Bulus Raya No.49, Jakarta Selatan 12440, Indonesia

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ABSTRACT

Interventional cardiology is a minimally-invasive imaging procedure that allows medical doctor to evaluate and treat structural heart diseases. Due to its main advantages of avoidance of the scars and pain, as well as long post-operative recovery, interventional cardiology procedures have rapidly been growing. However, the increasingly complex and time-consuming procedures in interventional cardiology may increase the radiation exposure received by patients. This paper describes a study to measure patient radiation doses in terms of air kerma and kerma air-product (KAP) for various types of interventional cardiology procedures conducted in Indonesia. The measurements were performed at the interventional cardiology or cardiac catheterization facilities in sixteen hospitals in ten cities in Indonesia during the years of 2015 to 2019. A total of 147 procedures conducted on adult patients were used in this study. The type of procedure, total KAP, and air kerma were recorded after each procedure was completed. The demographic data of the patients were also recorded. The results showed that the mean air kerma and KAP measured for CA (coronary angiography) procedure were 680.73±57.85 mGy and 12.52±5.86 Gy cm^2, respectively, while the values for PCI (percutaneous coronary intervention) procedure were 890.66±38.76 mGy and 20.18±9.37 Gy cm^2, respectively. These results are well within the ranges reported by other previous studies. The results are somewhat affected by the body mass index of patients, while the fatal cancer risks among patients of CA and PCI procedures are comparable with those among interventional radiology procedures patients.

INTRODUCTION

Interventional cardiology is a minimally-invasive imaging procedure that allows medical doctors to evaluate and treat structural heart diseases. It uses a catheter that is inserted into the blood vessel via the groin or arm and is then guided into the heart during radioscopy. Contrast dye is then injected while X-ray radiation is used to visualize and detect blocked or narrowed heart arteries, narrowed aortic valves, and/or cardiac pathologies.

Interventional cardiology started as a practice after the introduction of coronary inflatable angioplasty by Andreas Gruentzig in 1976 [1]. With the increased availability of medical aiding devices (*i.e.*, catheters and stents) and the improvement of robustness of fluoroscopy systems, the increasingly complex and time-consuming procedures in interventional cardiology may increase the radiation exposure of patients [2].

In Europe, the Atlas of the Interventional Cardiology has been developed by the European Association of Percutaneous Cardiovascular Interventions (EAPCI). The 2016 survey from 16 member countries reported the annual median number of procedures per million people performed as follows: 5131 diagnostic heart procedures, 2478 percutaneous coronary interventions (PCIs) procedures, and 48.2 transcatheter aortic valve implantation procedures [3]. This finding showed considerable heterogeneity in interventional cardiology procedure, and this is suggested to be associated with national economic resources.

*Corresponding author.
E-mail address: e.hiswara@batan.go.id
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In Spain, a nationwide survey on the number of cardiac catheterization and interventional cardiology performed during 1990-2017 have been reported [4]. Measurements of patient doses in interventional cardiology procedures have also been performed in Lebanon [5] and in Tanzania [6].

In the US, however, there was a tendency of decreasing frequency of this practice in the last decade. The number of cardiac interventional fluoroscopy procedures performed in the US has been decreasing from 4.6 million in 2006 to 4.1 million in 2016 [7]. This results in the reduction of collective effective dose from this procedure from 68 000 person-Sv to 42 000 person-Sv.

In Indonesia, interventional cardiology procedures have been implemented in most provincial central hospitals, as well as in some large private hospitals. Around 1250 cardiologists were registered performing interventional cardiology procedures in 256 cardiac catheterization labs in 160 hospitals in Indonesia in 2018 [8].

The purpose of this paper is to report the measurement of patient radiation doses in terms of air kerma and kerma air-product (KAP) for various types of interventional cardiology procedures conducted in Indonesia during 2015-2019.

THEORY

As with other radiation applications, radiation applications in the medical field, including in interventional cardiology, have potential effects on human health. Cases where patients developed skin lesions or even necrosis after receiving doses exceeding the threshold of deterministic skin effects have been widely reported [9-12].

Patients who undergo interventional cardiology procedures receive radiation doses in quantity of air kerma on the surface of the irradiation central point of skin, and of kerma-area product (KAP) in the irradiation area of skin. Air kerma is regarded as a measure of the risk of skin injuries (deterministic effects), while KAP is a measure of the risk for stochastic effects [13].

Several methods have been used to measure both air kerma dan KAP. The measurement of air kerma can be performed with such dosimeters as thermoluminescence dosimeters (TLDs), optically-stimulated luminescence dosimeters (OSLDs), or radiochromic films, while Gafchromic films and KAP meters can be used to measure the KAP. In modern X-rays machines, however, both air kerma and KAP can be measured by the ionization chamber mounted at the central X-ray beam, and the results are displayed in the monitor screen.

EXPERIMENTAL METHODS

The measurements of patient doses were performed at the interventional cardiology or cardiac catheterization facilities in sixteen hospitals in ten cities in Indonesia, namely, Jakarta, Bandung, Yogyakarta, Semarang, Surabaya, Denpasar, Padang, Banjarmasin, Makassar, and Manado, during the years of 2015 to 2019. A total of 147 procedures conducted to adult patients were used in this study.

Patient demographics consisting of gender, age, height, and weight were recorded before the procedures were started. The body mass index (BMI) was calculated by dividing the patient weight in kilograms with the square of height in meters. The type of procedure, total KAP, and air kerma were recorded after each procedure was completed.

Since all X-ray machines used were of modern types, air kerma and KAP had already been measured, and further calculated, by a transparent ionization chamber mounted in the X-ray tube assembly between the collimators and the patient, and the result was presented in the monitor screen of the X-ray machine. Air kerma is simply measured in a reference point located 15 cm from the isocenter toward the X-ray tube, and KAP is calculated by multiplying air kerma with the area of the X-ray beam incident.

RESULTS AND DISCUSSION

Every hospital uses its own terms in describing the interventional procedures it performs. Since the terminologies are so diverse, the terms used by the UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) is used here to simplify them. As can be seen in Table 1, the classification made by the UNSCEAR in its questionnaire for global survey of medical exposure [14] is used to classify the terms of procedures used in hospitals. The full terms of abbreviations are presented in Table 2.

The demographic data of the patients is provided in Table 3. According to the Ministry of Health [15], an adult who has a BMI of ≥ 25.0 and <27.0 can be categorized as overweight, and BMI of ≥ 27.0 is regarded as obese. It can be seen from Table 3 that CA patients have the tendency to be overweight, while some of PCI patients can be regarded as obese.

Table 1. Grouping of procedure based on a modified UNSCEAR classification.

Term of procedures used by hospitals	UNSCEAR classification
Ablation, ASO, AVO, BPV, CA, CAG, cardiac, cathscan, DCA, DCA adhoc, LAA, LL diagnosis, PA, PAC, PAC standby, PAC standby PCI, pericardial synthesis, RHC, TFCA, PTMC	Thoracic intervention, or CA
Angio, angio+elective PTCA, arteriography, CAG PCI, catheterization, catheter + stenting, catheter + stenting 3 position, early PCI, elective PCI, PAC standby PCI, stenting, PCI, PCI stent, PCI RCA, primary PCI, PCI venticulography, PTCA	PCI

Table 2. Full terms of abbreviations.

Abbreviation	Full term
ASO	Arterial switch operation
AVO	Aortic valve opening
BPV	Balloon pulmonary valvuloplasty
CA	Coronary angiography
CAG	Coronary angiogram
DCA	Directional coronary atherectomy
LAA	Left atrial appendage
LL	Local lysis
PA	Pulmonary artery
PAC	Premature atrial contraction
PCI	Percutaneous coronary intervention
PTCA	Percutaneous transluminal coronary angioplasty
PTMC	Percutaneous transvenous mitral commissurotomy
RCA	Right coronary artery
RHC	Right heart catheterization
TFCA	Thin fibrous cap atheroma

Table 3. Patient demographics in this study.

Variable	CA	PCI
Number (*n*)	51	96
Age (y)	62±12	60±14
Weight (kg)	68±20	70±18
Height (m)	1.61±0.12	16.0±0.15
BMI (kg/m^2)	26.2±2.6	27.3±1.9

Internationally, in the last few decades, the prevalence of obesity has risen both in developed and developing countries, with 1.46 billion adults being overweight and of them 402 million are obese [16]. This can be confirmed with the situation in Indonesia, where 13.6 % and 21.8 % of adult population are overweight and obese, respectively [15].

The BMI data of interventional cardiology patients from this survey can be compared with those of Brindhaban of 31-32 [17], and of Osei of 28.8 [18]. It shows that the BMI obtained from this study is relatively lower than those of Brandhaban and Osei.

The lower the BMI, the less the values of air kerma and KAP received by patient. This can be observed in Table 5 by comparing the results of measurement by Brandhaban and by this study.

An obese patient gives challenges in terms of attenuation of X-ray beam, resulting in increased noise and increased motion artifact due to the increased exposure time necessary [19]. The solution to these challenges is increasing the mAs dan kVp; however, this will raise the radiation dose to patient. The increase of patient dose due to obesity during coronary angiography procedures was also confirmed by Madder *et al*. [20].

Table 4 shows the results of measurements for the interventional cardiology procedures grouped previously. As can be seen, the CA procedure gave the highest air kerma to the patients, while the highest KAP was received by patients who underwent PCI procedure. These results include those that have been previously reported [21].

According to Table 3, the BMI of patients who underwent PCI procedures was relatively higher than those of CA procedures. This pattern is also seen in terms of air kerma and KAP received by patients. As can be seen in Table 4, PCI procedures gave both air kerma and KAP that were higher than CA procedures for patients.

Table 4. Mean patient doses in interventional cardiology procedures during 2015-2019.

Procedure	Number of patients	Air kerma (mGy)	KAP (Gy cm^2)	Mean fluoro time (min.)
CA	51	680.73±57.85	12.52±5.34	24.52±5.86
PCI	96	890.66±38.76	20.18±9.37	15.57±8.34

According to Riabroi, *et al*. [12], a single dose that exceeds 2 Gy may cause skin epilation or cataract. The acute radiation of 7 and 12 Gy may result in permanent epilation and skin necrosis. By comparing the air kerma measured as shown in Table 4 with a dose of 2 Gy that may cause skin epilation, it can be suggested that the patients may not develop any skin injuries.

Table 5 shows a comparison of air kerma and KAP values measured in this study with those other studies. It is worth to note that in Järvinen *et al*. [2], Ngaile *et al*. [6], and Brindhaban [17], DAP (dose-area product) was used instead of KAP. Per definition, DAP is equal to KAP × (1-*g*), where g is the fraction of energy charged particles lost in radioactive processes in the material. However, since the value of g is only fraction of percent, DAP and KAP has then practically the same value.

In general, Table 5 shows that all referred studies revealed that PCI procedures gave both air kerma and KAP to patients that were higher than CA procedures. This study also showed the same pattern.

Table 5. Comparison of air kerma and KAP with other studies.

Procedure	Air kerma (mGy)	KAP (Gy cm^2)	Fluoro time (min.)	BMI (kg/m^2)	Ref.
CA	680.73	12.52	24.52	26.2	This study
CA	-	30	6.0	28.4	[2]
CA	830.9	58.3	10.6	26.2	[6]
CA	264	31.4	9	-	[9]
CA	412	32	1.62	32	[16]
PCI	890.66	20.18	15.57	27.3	This study
PCI	-	75	18.4	28.4	[2]
PCI	1804.7	104.5	23.2	25.1	[6]
PTCA	596	74.2	2.1	-	[9]
PCI	857	118	5.61	31	[16]
PCI	1384.7	80.2	12.7	28.8	[17]

As shown in Table 5, the BMI values found in this study (26.2-28.4 kg/m^2) are well within the ranges reported in other studies (25.1-31 kg/m^2). However, in terms of fluoro time, CA procedures of this study and study of Saeed [9] needed a longer time to perform compared with the time to perform PCI procedures. This might be due to the cardiologists in facilities with shorter fluoro time to perform the CA procedure having more experience than those in this study and in study of Saeed.

Table 6 shows fatal cancer risks to patients who underwent CA and PCI procedures in this study. The fatal cancer risk for PCI patients was shown to be higher than that for CA patients. This finding is consistent with the pattern of air kerma and KAP received by patients, which were also higher for PCI procedure compared with CA procedure.

Table 6. Fatal cancer risk among interventional cardiology patients.

Procedure	KAP (Gy cm^2)	Conversion coefficient (mSv/Gy cm^2)[a]	Effective dose (mSv)	Fatal cancer risk[b]
CA	12.52	0,18	2.2644	9.28×10^{-5}
PCI	20.18	0.21	4.2378	1.74×10^{-4}

[a] Conversion coefficient values were taken from NCRP Report 60 as cited by the UNSCEAR. [14]

[b] Nominal risk coefficient for adults of 4.1×10^{-2} Sv^{-1} [22] was used to calculate fatal cancer risk.

The value of fatal cancer risk among CA and PCI patients can be compared with that from some procedures in interventional radiology, i.e. from a single head CT procedure, which is 1:10 000, or 1.0×10^{-4} [23], from CT angiography, which is 1:27 778, or 3.60×10^{-5} [24] and from mammography procedure, which is 1:5650, or 1.77×10^{-4} [25]. This value of comparison suggests that fatal cancer risk for CA and PCI patients are comparable with that for interventional radiology patients..

CONCLUSION

This study showed that the air kerma and KAP to the patients during CA procedures are 680.73±57.85 mGy and 12.52±5.34 Gy cm^2, respectively. It has also found the same parameters are 890.66±38.76 mGy and 20.18±9.37 Gy cm^2, respectively, for PCI procedures. These results are within the ranges reported by other studies, and somewhat affected by the body mass index of patients. Furthermore, the fatal cancer risks among patients CA and PCI procedures are found to be comparable with those underwent interventional radiology procedures.

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AUTHOR CONTRIBUTION

The first author is the main contributor of this paper. All authors read and approved the final version of the paper.

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