Occupational dose during an interventional radiology procedure

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Abstract. The development of radiation utilization, in medical application, increases every year. One of them was the interventional radiology facility. Interventional radiology has been chosen to replace invasive procedures for diagnosing and cure several cases of the blood system. However, large radiation exposure for radiation workers remains the main potential of an occupational hazard. Therefore, radiation protection plays an important role in ensuring the occupational dose does not exceed the regulated limits by BAPETEN. The purpose of this study was to determine the estimated effective dose (mSv) received by radiation workers undergoing interventional procedures. Occupational doses were measured using the thermoluminescence dosimeter (TLD) chips which placed on critical organ areas such as thyroid, thorax and gonads/ovaries during interventional procedures. In this study, the interventional procedures carried out for PCI, embolization, PTCA, limb intervention, thoracic intervention and cerebral intervention. The TLD was then read using the TLD Reader 3500 Harshaw. The results of this study showed mean effective dose received by doctors, nurses and radiographers in several hospitals in Indonesia due to carrying out interventional procedures was 0.043 ± 0.034, 0.048 ± 0.064 and 0.047 ± 0.031, respectively. The dose received by the radiation workers is still below the limit regulated by BAPETEN, which is 20 mSv/year. These doses were varied based on the type of interventional procedure and the time of fluoroscopy.

1. Introduction
The radiation utilization in the medical application has been increasing every year. One of them was the development of interventional procedures[1]. Those procedures were widely chosen to replace the invasive procedure because it permits shorter recovery time and only requires a very small incision. Interventional procedure using radiation as guidance to the manipulated small instrument such as catheters, guide wires, balloons, and stents through blood vessels or another pathway in the body to cure the diseases [2]. Indonesia was one of the countries which rapidly performed interventional procedure utilization. Nowadays, almost all of the government and private hospitals have the facility to perform interventional procedures not only for diagnostic but also to cure the disease.

The previous study was discussed about the measurement of radiation dose received by the radiation worker during interventional radiation using several methods. The general methods used to estimate the occupational dose was using thermoluminescence dosimeter (TLD) at critical organs such as thyroid, thorax and gonads/ovaries. The research in Nuclear Medicine Department Kuwait using TLD to measure the dose of Hp(10). Those research conclude that the dose received by the radiation workers not more than 4 mSv [3]. Suleiman, et al. also conducted the measurement of occupational dose in Sudan. They attached the TLD at radiation worker apron during performed interventional procedures and the result...
was the cardiologist received the highest dose [4]. Another previous study during fluoroscopy guiding procedure concluded that the highest projection of occupational dose in one year by radiation workers was 8 mSv [5].

Interventional procedures were complicated which consequently delivering high radiation exposure for the radiation workers [6], [7]. Although the interventional procedures have many advantages, however it requires long time radiation exposure. Radiation workers who conducted interventional procedures are at high risk of radiation exposure. Owing to the fact that, radiation protection has very important roles in making sure radiation exposure received by the radiation workers did not exceed the limit regulated by BAPETEN which is 20 mSv/year. The implementation of radiation protection in Indonesia especially for the radiation worker performed interventional procedures has been good however the research regarding the estimation of the occupational dose received by those workers never done before. Hence, the purpose of this research was to estimate the effective dose received by radiation workers during interventional procedures in Indonesia.

2. Methods

The data for the research was collected at eight government and private hospitals in Java Island and Bali Island Indonesia. The measurements were performed on radiation workers which consist of 165 doctors, 50 radiographers and 136 nurses who conducted interventional procedures. In this study, TLD-100 (LiF:Mg, Ti) chips which size 3,2x3,2x1,5 mm from Thermo Scientific Harshaw were using to measure the radiation dose. Every three chips of TLD were packed using plastic and then attached at four positions on radiation workers. The TLD placed inside and outside of lead shielding at thyroid and gonad/ovaries area. The placement of TLD conducted before undergoing the interventional procedure and detached after it finished. The irradiated TLD was read using TLD Reader Harshaw 3500.

The estimated effective dose for Hp(10) which received by radiation workers determined using the methods recommended by Niklason [8], as follows:

\[ E = 0.02 (H_{os} - H_{iu}) + H_{iu} \]  

Where \( H_{os} \) is the radiation dose from the TLD which placed outside at thyroid area lead apron and \( H_{iu} \) is the radiation dose placed inside at gonad/ovaries lead apron.

3. Results and Discussion

In this study, the interventional procedures performed consist of Percutaneous Coronary Intervention (PCI), Embolization, Percutaneous Transluminal Coronary Angioplasty (PTCA), Limb Intervention, Thoracic Intervention and Cerebral Intervention. The effective dose is used to estimate the occurrence of stochastic effects and also ensure that the dose received by radiation workers still below the limit recommended by IAEA (i.e. 20 mSv/y).

The effective dose average received by doctors, nurse and radiographers were 0.043±0.034, 0.048±0.064 and 0.047±0.031 mSv, respectively. The radiation dose received by the radiation workers still within the limit recommended by IAEA which was 20 mSv/year[1].

Based on the type of interventional procedures performed, the effective dose received by radiation workers presented in Table 1. In this study, PCI was the most often interventional procedure performed. Internationally, PCI also the most often interventional procedure performed in the United States[9]. Cerebral Intervention procedures have the highest effective dose followed by PCI, PTCA, Limb Intervention, Thoracic Intervention and Embolization procedures, respectively.

The doctor received the highest effective dose for all types of procedures except for Limb Intervention and Cerebral Intervention. The highest effective doses on Limb Intervention and Cerebral Intervention procedures were received by radiographer and nurse, respectively. Ideally, the doctors will receive the highest effective dose due to the position of the doctor which the nearest to the patient during performed the interventional procedures. The anomaly was occurred possibly due to the position change of radiographers and nurses during a performed interventional procedure to help the doctors [10]. Table
1. showed that effective dose received by the radiation worker lower than the dose limit recommended by ICRP and also the previous studies [3][6].

Table 1. The effective dose received by the radiation worker based on the type of interventional procedure.

| Interventional procedure | Number of procedure | Radiation worker | Mean (mSv) | Median (mSv) | Min (mSv) | Max (mSv) |
|--------------------------|---------------------|------------------|------------|--------------|-----------|-----------|
| PCI                      | 33                  | Doctor           | 0.050      | 0.040        | 0.003     | 0.242     |
|                          |                     | Nurse            | 0.047      | 0.043        | 0.001     | 0.139     |
|                          |                     | Radiographer     | 0.047      | 0.041        | 0.001     | 0.136     |
| Embolization             | 5                   | Doctor           | 0.035      | 0.034        | 0.008     | 0.068     |
|                          |                     | Nurse            | 0.024      | 0.024        | 0.024     | 0.024     |
|                          |                     | Radiographer     | 0.022      | 0.022        | 0.016     | 0.027     |
| PTCA                    | 8                   | Doctor           | 0.044      | 0.036        | 0.004     | 0.110     |
|                          |                     | Nurse            | 0.057      | 0.059        | 0.008     | 0.098     |
|                          |                     | Radiographer     | 0.087      | 0.087        | 0.087     | 0.087     |
| Limb Intervention        | 2                   | Doctor           | 0.041      | 0.057        | 0.008     | 0.058     |
|                          |                     | Nurse            | 0.044      | 0.044        | 0.039     | 0.048     |
|                          |                     | Radiographer     | 0.102      | 0.102        | 0.102     | 0.102     |
| Thoracic Intervention    | 19                  | Doctor           | 0.031      | 0.023        | 0.001     | 0.089     |
|                          |                     | Nurse            | 0.027      | 0.027        | 0.002     | 0.069     |
|                          |                     | Radiographer     | 0.033      | 0.034        | 0.010     | 0.064     |
| Cerebral Intervention    | 3                   | Doctor           | 0.056      | 0.029        | 0.000     | 0.063     |
|                          |                     | Nurse            | 0.079      | 0.029        | 0.011     | 0.685     |

Figure 1. Dose distribution on thyroid and gonad/ovaries based on the type of procedure.

Figure 2. Fluoroscopy times average based on the type of procedure.

The dose distribution according to the TLD which placed on the thyroid and gonad/ovaries area presented in Figure 1. The TLD which placed on the thyroid area received a relatively higher radiation dose than TLD which placed on the gonad/ovaries area. The thyroid area was closer to the radiation source than the gonad/ovaries area during the interventional procedure performed. Moreover, thyroid
was a critical organ that was susceptible to radiation damage. Therefore, radiation protection must be applied to the radiation worker to ensure radiation safety.

Figure 2 showed the fluoroscopy time for the type of each interventional procedure in this study. Based on Figure 2, the longest fluoroscopy time occurred during Limb Intervention followed by the PTCA procedure. Generally, the effective dose will be correlated by fluoroscopy time. The longer fluoroscopy time the greater the effective dose however the fact was cerebral intervention procedure has the highest effective dose although it has the shortest fluoroscopy time. Those have occurred because of interventional radiation involving by some parameters such as the skill of radiation worker, the chosen radiation area also the used technique[11].

4. Conclusion
The effective dose received by radiation workers in Indonesia varied based on the type of interventional procedure and fluoroscopy time. The effective dose received by doctors, nurse and radiography were 0.043±0.034, 0.048±0.064 and 0.047±0.031, respectively. Those results did not show a significant difference which was 0.04 mSv. The effective dose received by the radiation worker still within the dose limit recommended by IAEA. Fluoroscopy time did not correlate directly with the effective dose received by the radiation worker because it also involves other parameters.

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