Occupational radiation dose during fluoroscopy guided interventional procedures at Institut Kanser Negara

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Abstract. Fluoroscopy-guided interventional (FGI) tends to involve long-term procedures that increase the fluoroscopy time and the dose area product (DAP). Therefore, radiation protection is a major concern for interventional radiology staff. This study signifies the occupational and the radiation doses for interventional radiology staff, in particular, non-physician in order to clarify the current dose level for radiographers and nurses. The occupational doses were compared among interventional radiology staff in Institut Kanser Negara (IKN), Putrajaya, Malaysia where 230 patients underwent FGI procedures were observed in one-year. The occupational doses of interventional radiologist (IR), medical officer (MO), radiographer and nurse were recorded using two optically stimulated luminescence dosimeter (OSLD), one worn over and one under their protective aprons. The occupational dose (effective dose) indicated that the IR, MO, radiographer and nurse with double OSLDs were 9.82, 7.91, 6.42 and 6.02 mSv, respectively. The effective dose of IR, MO, radiographer and nurse were 7.63, 7.91, 6.42, 5.66 mSv, respectively using a single OSLD. It has shown a statistically significant difference in the effective dose of double worn OSLDs and one OSLD of (p < 0.05) for interventional radiology staff. In both methods, IR > MO > radiographer > nurse was the highest effective dose in the interventional radiology staff. However, the occupational dose of single OSLD was found to be lower than double OSLDs. It is highly recommended that interventional radiology staff to use double OSLDs during the FGI procedures in order to determine the occupational dose accurately.

1. Introduction

Fluoroscopy-guided interventional (FGI) procedures that provides minimal invasive image-guided and offer advantages over surgery for diagnosis and treatment of disease. FGI procedures are often complex. Hence, high radiation doses were delivered to medical staff and patients [1].

According to Vano et al [2], the interventional radiologist (IR) was at high risk of radiation-induced of eye injury and should consider an eye protection in order to prevent cataracts. From the previous study conducted by Haskal and Worgul [3], cataracts were found in five of 59 with (8%) of screened interventional radiology physicians, and an additional 22 subjects with (37%) had a small paracentral dot-like opacities in an early sign of cataracts. In addition, Ainsbury et al [4] indicated that the threshold for the development of radiation-induced cataract was lower than previously estimated in
several studies. Therefore, for interventional radiology staff, radiation protection and dose evaluation were imperative.

Most occupational dose studies for interventional radiology staff mainly focused on the physician. Few studies were found on non-physician occupational doses, namely radiographer and nurse [5,6]. In addition, Institut Kanser Negara (IKN) interventional radiology staff is currently using only single optically stimulated luminescence dosimeter (OSLD) under the apron. This study depicts the occupational radiation dose for staff in interventional radiology, particularly for non-physician.

2. Materials and methods

The occupational dose of interventional radiology staff (interventional radiologist, medical officer, radiographer and nurse) was observed at Institut Kanser Negara (IKN), during the FGI procedure. The IKN was built to provide facilities specialised in oncology, radiotherapy and nuclear medicine. The majority of the FGI procedure conducted at IKN is for cancer patients. This study was conducted from February 2017 to January 2018 (one year). During the FGI procedure, Philips Allura Xper FD20/20® biplane system (Philips Healthcare, Best, The Netherlands) was used to examine 230 patients.

Two combinations of additional commercial lead shielding devices, namely table-side drapes of (0.5 mm lead equivalent) and acrylic lead shields suspended from the ceiling of (0.5 mm lead equivalent) were used in this FGI procedure. During the procedure, the interventional radiology staff will wear a protective apron (0.25 mm lead equivalent but with overlap in front to make it 0.5 mm on the front and 0.25 mm on the back).

During the FGI procedure, the occupational dose (effective dose) of the interventional radiology staff was determined using an OSLD. InLight dosimeter (Landauer Inc., USA) is the type of OSLD used for this evaluation. Each InLight dosimeter contains a slide with four of these OSL detectors.

All the interventional radiology staff wore double OSLDs in a protective apron of 0.25 mm lead equivalent one side on the chest and one on the outside of thyroid collar.

| Method          | Algorithm                        | Reference          |
|-----------------|----------------------------------|--------------------|
| Single dosimeter| \( E_i = H_w \)                  | Chida et al. [7]   |
| Double dosimeters| \( E_z = 0.84H_w + 0.051H_N \)  | von Boetticher et al. [8] |

\( H_w \): \( H_p(10) \) under the protective apron on the chest;
\( H_N \): \( H_p(10) \) outside the thyroid collar

The effective doses were calculated separately by using two different algorithms (see Table 1). The conversion factors were applied in these algorithms to the measure the doses at two places; outside the thyroid collar (\( H_N \)) and under the protective apron (\( H_w \)).

The occupational doses (effective dose) of the interventional radiology staff by utilising double OSLDs and single OSLD were compared (only under the protective apron) to the same individuals. The read-out process was performed using the Landauer MicroStar™ reader system at the Physics Laboratory, Universiti Teknologi Malaysia (UTM).

Statistical analysis was carried out using the Statistical Package for Social Science (SPSS Statistics version 24, IBM). The descriptive statistics were used to compare effective dose for the occupational dose between the interventional radiologist (IR), medical officer (MO), radiographer and nurse. Non-parametric were preferred since the data were not normally distributed [9]. In order to compare between the interventional staff and the data for the two groups (the single OSLD dosimeter and double OSLDs), non-parametric statistics were used in Wilcoxon Signed Rank test. Hence, the statistical significance was defined as \( p < 0.05 \).

3. Result
Figure 1 shows that the effective dose for interventional radiology staff using double OSLDs was higher than single OSLD, but the higher effective dose order was still the same as IR > MO > radiographer > nurse.

Table 2. Effective dose for Interventional Radiology Staff

| Interventional Radiology Staff | Effective dose (mSv) |      |      |
|-------------------------------|----------------------|------|------|
|                               | Single OSLD         | Double OSLDs | p    |
| Interventional radiologist (IR)| 7.63                | 9.82  | <0.05|
| Medical officer (MO)            | 7.06                | 7.91  | <0.05|
| Radiographer                   | 6.02                | 6.42  | <0.05|
| Nurse                          | 5.66                | 6.02  | <0.05|

Table 2 shows the effective dose of single OSLD and double OSLDs for interventional radiology staff. The findings show that the occupational dose (interventional radiologist, medical officer, radiographer and nurse) of using single OSLD and double OSLDs was significantly different by using a Wilcoxon Signed Rank test. Apart from that, a Wilcoxon Signed Rank test also showed that the occupational dose of the interventional radiology staff itself was significantly different. Therefore, the statistically significant difference was defined as $p < 0.05$.

4. Discussion

Two types of radiation effects exist, namely stochastic (i.e., radiation-induced cancer) and deterministic (i.e., cataracts). In order to estimate the risk of stochastic effects, the effective dose, and the regulatory effective dose limit of (20 mSv) were used to ensure that the limit occurrence of stochastic effects was maintained at acceptable levels [10]. In addition to that, the dose equivalent was used to evaluate the risk of deterministic effects, and the regulatory dose equivalent limit of the eye lens with 150 mSv was used to avoid deterministic effects (tissue reactions) [10]. Nevertheless, effective quantities of body-related dose protection cannot be measured. The 10 mm dose equivalent was identified using a dosimeter and was used to measure effective dose, while the 0.07 mm dose equivalent, was also identified using a dosimeter and was used to measure dose equivalent [10]. In
addition, the 10 mm dose equivalent of each dosimeter was converted into an effective dose using calculation algorithms when double monitoring dosimeters were used.

As with interventional radiology physicians, it is important to evaluate the occupational dose of interventional radiology nurses since many interventional radiology nurses are close to the source of scattered radiation (such as the patient). However, the annual occupational dose for interventional radiology nurses has not been described in a detailed report.

Efstathopoulos et al [11] used thermoluminescence dosimeters outside the protective apron to measure the occupational dose of interventional radiology staff (physicians and nurses). In addition, the effective dose was not included in this study. Hence, the annual occupational doses (effective dose and dose equivalent) obtained were compared with interventional radiology staff using the double dosimeters method.

The annual occupational dose (effective dose) for all the interventional radiology staff (IR, MO, radiographer and nurse) was below the maximum permissible radiation limits for radiation workers. According to Balter et al [12] and Dauer et al [13], one probable reason for this was that appropriate education in radiation safety for the interventional radiology staff helps to optimise radiation protection throughout the procedures. In other words, the education and training on radiation protection for non-physicians (radiographer and nurse) are essential.

In most cardiac laboratories, double dosimeters were used in order to evaluate the interventional radiology physician dose [14]. However, other interventional radiology staffs such as radiographer and nurse wear a single dosimeter under the apron. The annual occupational doses in this study were determined by utilising double OSLDs in non-physicians and physicians (radiographer and nurse). Jarvinen et al [15] reported an effective dose of single and double dosimeters for interventional radiology staff but no comparison was found between other interventional radiology staff and the occupational dose. Kuipers and Velders [16] stated that an effective dose of interventional radiology staff by utilising both single and double dosimeters were found only for IR.

Therefore, the evaluation of effective doses was focused in this study among interventional radiology staff, including non-physicians obtained using the double dosimeters method. The annual effective dose nurses for interventional radiology staff was significantly lower than physicians and radiographer. Evidently, nurses were found to be closer to the patient during procedures should be higher than radiographer but lower than the physicians. It is significantly different from a study reported by Chida et al [5] which shows that nurses have a higher occupational dose than radiologic technologist. Therefore, it is necessary to evaluate the occupational doses of non-physicians accurately, particularly in nurses.

From the previous study conducted by Kuipers and Velders [16], stated that a more accurate estimation could not be considered as the effective dose of interventional radiology when double dosimeters were used instead of single dosimeter. In contrast, Jarvinen et al [15] stated that the single dosimetry algorithms were more likely to underestimate the effective dose in some cases and double dosimeter were preferred.

Single OSLD was used in non-physicians during the procedures prone to underestimate the effective dose. But, the single OSLD worn outside a protective apron is a good screening for eyes and extremities dose. Therefore, since the dose is not uniform for all non-physicians, the suitable method in order to evaluate the occupational dose of interventional radiology staff is by introducing the double dosimeter approach. It is believed that, in order to evaluate the occupational dose accurately throughout the interventional radiology process, the double dosimeters method should be used, not only by physicians but also for other interventional radiology staff including nurses.

During this study, no dose for interventional radiology staff exceeded the regulatory limit. Apart from that, the annual occupational dose was in order IR > MO > radiographer > nurse for interventional radiology staff. The occupational dose of single OSLD under the apron was much lower than the dose of double OSLDs in all interventional radiology staff.

5. Conclusion
The annual occupational dose (effective dose) is in order of IR > MO > radiographer > nurse of interventional radiology staff. It is highly recommended the introduction of portable shielding and right positioning are required during FGI procedures to reduce the unnecessary exposures to IR staff. Double dosimeters were suggested to be used in order to evaluate the occupational dose accurately during FGI procedure, not only in physicians but also in other interventional radiology staff particularly non-physicians.

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