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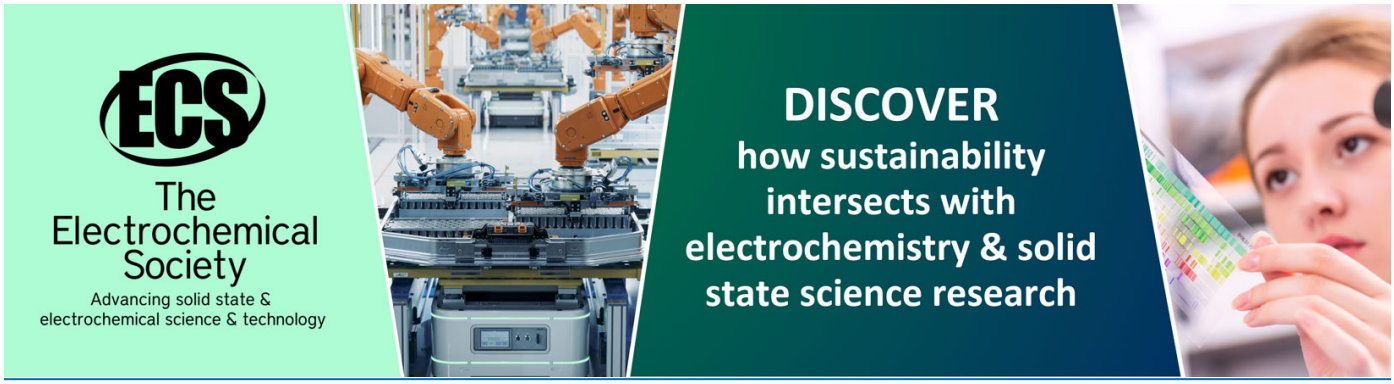

Radiation dose to physicians' eye lens during interventional radiology

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Abstract. The demand of interventional radiology has increased, leading to significant risk of radiation where eye lens dose assessment becomes a major concern. In this study, we investigate physicians' eye lens doses during interventional procedures. Measurement were made using TLD-100 (LiF: Mg, Ti) dosimeters and was recorded in equivalent dose at a depth of 0.07 mm, Hp(0.07). Annual Hp(0.07) and annual effective dose were estimated using workload estimation for a year and Von Boetticher algorithm. Our results showed the mean Hp(0.07) dose of 0.33 mSv and 0.20 mSv for left and right eye lens respectively. The highest estimated annual eye lens dose was 29.33 mSv per year, recorded on left eye lens during fistulogram procedure. Five physicians had exceeded 20 mSv dose limit as recommended by international commission of radiological protection (ICRP). It is suggested that frequent training and education on occupational radiation exposure are necessary to increase knowledge and awareness of the physicians' thus reducing dose during the interventional procedure.

1. Introduction

The upper hand of interventional radiology in medical imaging has contribute to the growth of interventional procedures. It involves sophisticated techniques to visualize the inside of the human body with the guidance of a variety of catheters, needles, and guidewires. An important concept of interventional procedures which differ from other procedures is that the procedures are minimally invasive with shorter time of recovery, makes it more preferable for the physician. However, despite the benefits, some interventional procedure can deliver high dose of radiation to both patient and staff due to long fluoroscopy time and high-dose fluoroscopy modes.

Physicians are of particular concern as they are exposed to scattered radiation from the patient and in some cases, they are directly exposed to x-ray even though they are not supposed to be. Multiple previous studies showed high radiation exposure to the hands of physicians during fluoroscopy-guided procedures which might be due to direct exposure during the procedures [1–3]. Eye lens are also in particular interest as it is sensitive to radiation and overexposure of eyes can lead to cataract, vision loss, or even blindness. Many studies have been done to investigate the eye lens dose of physicians during interventional radiology and one study found that it was higher than the limits [4]. In 2011, ICRP has alerted the radiological community by lowering threshold dose of staff eye lens from 150 mSv per year

to 20 mSv per year [5]. Even though many eye lens doses are well below the limit, it will be exceeded if the doses are compared to the latest ICRP recommendation of 20 mSv per year. Thus, continuous review of physicians eye lens doses during interventional procedures are recommended [4, 6].

Most data found were based in European Countries and inadequate study of physician's eye lens doses during interventional procedures in Malaysia has become motivation to initiate the current study. The objectives include to assess eye lens doses of physician during interventional procedures and to evaluate the compliance of current practice with dose limit proposed by ICRP.

2. Methodology

In Hospital Sultanah Aminah (Johor, Malaysia), the eye lens radiation exposure of 30 physicians during various interventional procedures were collected. All examinations include antegrade pyelography, barium swallow, cystogram, endoscopic retrograde cholangiopancreatography (ERCP), hysterosalpingogram (HSG), percutaneous nephrostomy (PCN), and urethrogram, were done in the same fluoroscopy room, equipped with MultiDiagnost Eleva's C-Arm. Double dosimetry method were used where thermoluminescence dosimeter, TLD-100 chips, worn on two position: under the lead apron at the waist level, and at both sides of the eyes. TLD-100 chips which are made of LiF: Mg, Ti, with the dimension of $3.2 \times 3.2 \times 3.2$ mm^3, were initially calibrated at Sondary Standard Laboratory (SSDL), Malaysian Nuclear Agency, for the purpose of coefficient factor determination. It was then annealed at 400°C for one hour and 100°C for two hours before being used.

The eye lens radiation exposure were recorded in terms of equivalent dose, Hp(0.07), and dose under the lead apron were recorded as Hp(10). The method was chosen based on the recommendation by the previous study where it was found to give better dose estimation compared to single dosimetry method [7]. Effective dose was calculated based on the following equation;

$$E = 0.84\, Hp(10) + 0.051\, Hp(0.07) \quad (1)$$

Equation (1) was known as Von Boetticher algorithm, derived based on ICRP 103 [8]. Annual eye lens dose and annual effective dose were estimated based on workload estimation for a year. Both annual doses were then evaluated to determine the compliance of the dose received with the dose limit as proposed by ICRP.

3. Results

In this study, eight different interventional procedures were selected, involving a total of 28 examinations and 30 physicians. 28 patients' variation in age and size is shown in table 1.

Table 1. Mean values (range) of patients' age and size.

Characteristics	Age (years)	Height (m)	Weight (kg)	BMI (kg/m^2)
Mean values (range)	48.75 (18-76)	1.55 (1.41-1.75)	53.18 (40.-75)	21.03 (15.63-26.89)

All patients are adult with average BMI of 21.03 which categorized as normal for adults. Protocol details were recorded for all investigated procedures as in table 2. Maximum and minimum values of DAP values and fluoroscopy time were in large variations. DAP ranged from 6 μGy.m^2 (HSG) to 639μGy.m^2 (antegrade pyelography). The shortest fluoroscopy time was recorded during cystogram (20 s) while the longest procedure was antegrade pyelography (577 s). Tube voltage setting for all procedures was 75 kV except for barium swallow (80 kV). For most of the procedures, tube current used was 220 mAs while the highest (400 mAs) was recorded during ERCP examinations.

Table 2. Mean values (range) of patients' radiation dose in terms of μGy.m^2 and other protocol details.

Protocol	Tube current (mAs)	Tube voltage (kV)	Fluoroscopy time (s)	DAP (μGy.m^2)
Mean values (range)	244.0 (220-400)	75.5 (75-80)	167.4 (20-577)	143.3 (6-639)

Overall, eye lens dose, Hp(0.07), and waist dose, Hp(10), were assessed for 30 physicians (table 3). In all procedures, all subjects use lead apron, thyroid collar, ceiling-suspended lead screen and table curtain. Hp(0.07) ranged from 0.02 mSv (urethrogram) to 0.96 mSv (fistulogram) for left eye and 0.02 mSv (urethrogram) to 0.43 mSv (ERCP) for right eye.

Table 3. Radiation dose exposure in terms of equivalent dose (mSv) to interventional radiology physician.

	Position	Mean	Median	Min.	Max.	Stand. Dev.
Hp(0.07)	Left	0.33	0.30	0.02	0.96	0.23
	Right	0.20	0.27	0.02	0.43	0.11
Hp(10)	Left	0.27	0.25	0.02	0.48	0.14
	Right	0.25	0.31	0.01	0.35	0.11

Even though the highest eye lens dose were recorded during fistulogram and ERCP, the highest average dose calculated by procedure was barium swallow (figure 1). Urethrogram has the lowest average eye lens doses compared to other procedure involved in this study. In addition, left eye lens dose were higher than right eye lens dose in most of the procedure.

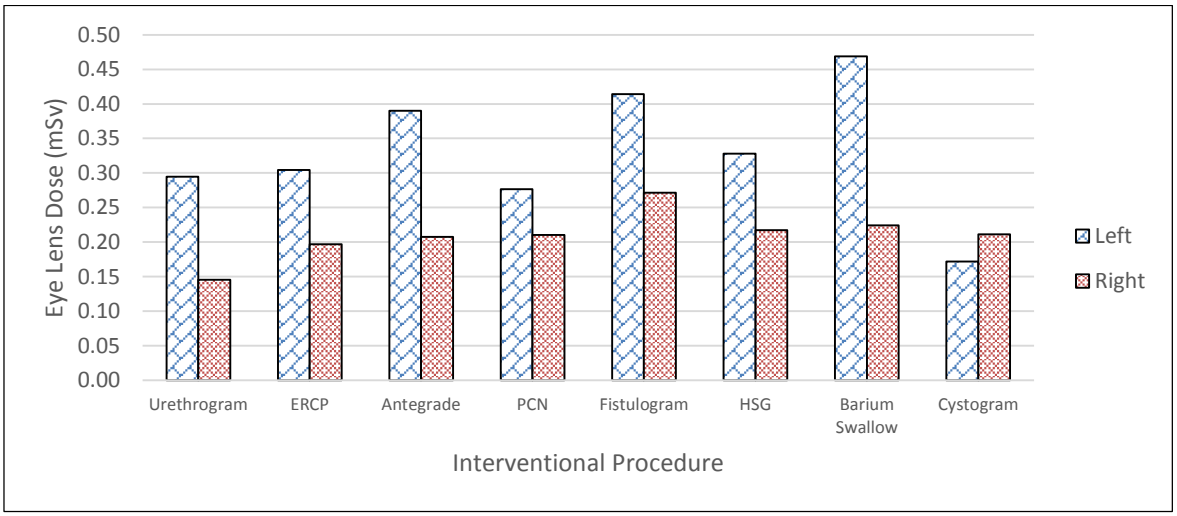

Figure 1. Average eye lens dose for each interventional procedures.

The data of eye lens dose were then used to assess annual eye lens dose of the physician. Annual eye lens dose represents the cumulative dose received by physician on eye lens for a year while annual effective dose reflects the risk of non-uniform dose distribution in terms of a uniform, whole body, and exposure for a year. Figure 2 shows the annual eye lens dose and annual effective dose estimated for all physicians. Mean values of annual eye lens dose were found to be 12.76 mSv with the highest value recorded was 29.33 mSv. For annual effective dose, mean values calculated was 10.99 mSv with the highest value of 17.32 mSv.

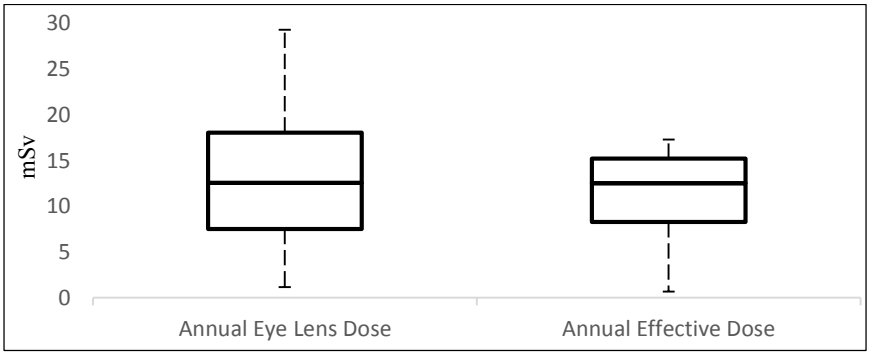

Figure 2. Estimated annual eye lens dose and annual effective dose.

4. Discussion

Overall view of the results gave a hint of radiation dose level received by physicians working in interventional suites. Wide variations of patients' dose may due to difference in BMI, duration of direct x-ray exposure (fluoroscopy time) and imaging protocol used by technologists. DAP were reported as they also attribute to occupational dose (scattered radiation) other than direct exposure of X-ray. High DAP value during antegrade pyelography is in correlation with fluoroscopy time recorded during the procedure, which was 577 seconds, highest among other procedure. This finding indicates the importance of physician knowledge, experience, and early preparation so that fluoroscopy time or exposure time can be reduced. In addition, it was found I all cases that none of the physicians wear an eyes protection or lead glasses during the procedures. Thus, contribute to unnecessary eye lens exposure where it could be reduced up to a factor of 10 with the use of lead glasses [9]. In fact, present eye lens dose were found higher than previous study [6, 10]. Similar trend was also found between present and previous dose where left eye lens were higher than right eye lens. This is due to the setting in the fluoroscopy room where x-ray tube and monitor are placed in a position that required left side of the physician received more exposure than right side.

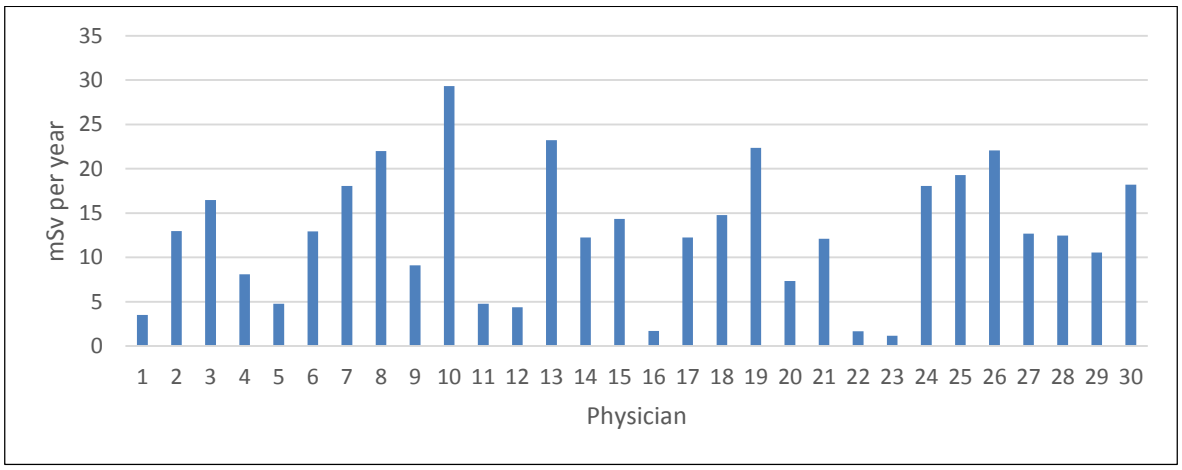

Figure 3. Annual eye lens dose received by each physician.

Five physicians had exceeded eye dose limit proposed by ICRP (20 mSv) with the highest reading of 29.33 mSv as in figure 3. These findings again emphasized the need of changing in physicians practice especially the use of lead glasses and appropriate training in particular procedure to reduce fluoroscopy time during interventional procedure are suggested. Training in radiation protection is also recommended for physicians to increase their awareness regarding radiation protection safety. For annual effective dose, all physicians dose are well below the dose limit recommendations of ICRP. However, precautions should be taken as biological effects of ionizing radiation (BEIR VII) proposed

that the generally accepted estimated excess relative cancer risk from an acute single dose of 100 mSv is 10%, or in other words, no radiation exposure are safe and they might contribute to the future cancer risk [11]. Therefore, proper radiation protection, minimize fluoroscopy time and keep away from exposure whenever possible are very important for physicians.

5. Conclusion

Our study has established data on physicians' eye lens dose using double dosimetry method. Physicians' eye lens dose was found higher as compared to previous studies. In fact, five physicians had exceeded annual eye dose limit of 20 mSv per year. The findings indicate the needs to reduced physicians' dose during interventional procedure where unnecessary exposure could be avoided by training and wearing proper protective device (lead glasses/googles). The present study involved many interventional procedure that varies in many aspects. Therefore, future work should concentrate on particular complex procedure to obtain much accurate result.

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