Special Article

Radiation Dose to Medical Staff in Interventional Radiology

Sornjarod Oonsiri MSc*,
Chotika Jumpangern MSc*, Taweap Sanghangthum MSc*,
Anchali Krisanachinda PhD**, Sivalee Suriyapee MEng**

** Department of Radiology, King Chulalongkorn Memorial Hospital*
*** Department of Radiology, Faculty of Medicine, Chulalongkorn University*

Objective: *The purposes of the present study were to determine the dose to medical staff in interventional radiology at different locations on the body measured by thermoluminescent dosimeter (TLD) and to relate the medical staff dose to patient dose measured by the dose-area product (DAP) meter.*
Material and Method: *The present study covered 42 patients in three interventional radiology procedures with three x-ray machines. Thermoluminescent dosimeters were stuck at eight positions on the radiologist's skin during the procedure. In addition, direct reading from the DAP meter placed in front of the collimator of the x-ray tube, was recorded to estimate the patient radiation dose.*
Results: *The surface dose to the primary radiologist showed maximum value at the left forearm of 407 µGy. The ratios between the maximum interventional radiologist surface dose and patient dose are 12.88 µGy per 10 Gycm^2 for transarterial oily chemoembolization TOCE (Siemens Polystar), 22.58 µGy per 10 Gycm^2 for transarterial oily chemoembolization TOCE (Siemens Neurostar), 148.29 µGy per 10 Gycm^2 for percutaneous transhepatic biliary drainage PTBD (Siemens Polystar) and 100.46 µGy per 10 Gycm^2 for endoscopic retrograde cholangiopancreatography ERCP (GE Advantx).*
Conclusion: *The interventional radiologist surface dose can be estimated from the mentioned ratio if the patient dose is measured. This will help the radiologists to avoid receiving an excess dose during their work.*

Keywords: *Thermoluminescent dosimeter, Dose-area product, Radiation dose*

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Radiological risk to medical staff in interventional radiology is a topic of major concern in medical radiation protection, due to the rapidly increasing use of fluoroscopy[1]. Furthermore, the fast development of interventional radiology in recent years has seldom, if ever, been matched by a parallel increase in the number of specialists[2]. Thus, workloads supported by interventional radiology staff are often great. In addition, since fluoroscopic image quality can be improved as radiation intensity increases, interventional radiology is prone to overexposure to both the patient and the staff. Various studies[1-5] have been performed to optimize interventional radiology. The purpose of the present study was to determine the dose of medical staff in interventional radiology at different locations on the body using thermoluinescent dosimeter (TLD) as occupational dosimetry. The relationship between occupational and patient doses was also established. A recent paper addressing staff radiation exposure in catheterization laboratories, stressed once again the importance of ability, good training and radiation protection awareness as key factors[6-10]. Unfortunately, the discomfort of the staff when using protective tools and/or some of these measures may impair the image quality, thereby slowing down the procedure.

Correspondence to : Suriyapee S, Department of Radiology, Faculty of Medicine, Chulalongkorn University, Rama IV Rd, Bangkok 10330, Thailand. Phone: 0-2256-4334, E-mail: ssivalee@yahoo.com

Material and Method

The thermoluminescent dosimeter (TLD) used in the present study was lithium fluoride (LiF) crystal doped with magnesium and titanium (LiF:Mg, Ti). TLD-

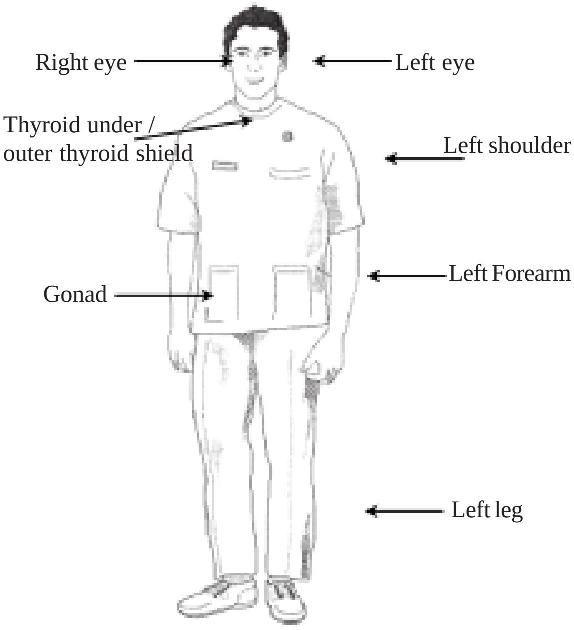

Fig. 1 Site for dose monitoring for radiologist

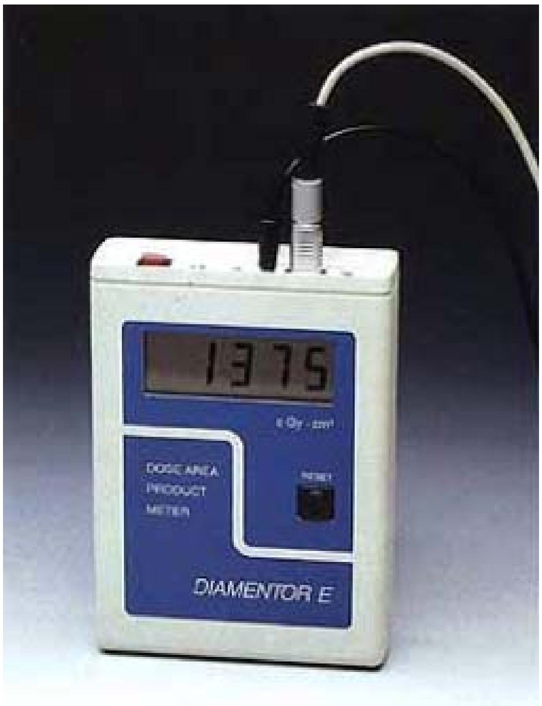

Fig. 2 Dose-area product meter (DAP)

100 chips from Harshaw TLD Bicron NE-Technology with the dimension of 3.2 mm × 3.2 mm × 0.89 mm were calibrated for the sensitivity, energy response, linearity, and minimum detectable dose. Three TLD-100 chips were loaded in each plastic tube and placed on the surface of both eyes, thyroid under thyroid shield, thyroid outside thyroid shield, left shoulder, left forearm, and left leg of radiologists who worked with the patient throughout the procedure. The data were presented as the average and range in the form of tables and histogram as well as pictures. The TLD[11-13] was placed at the left side of the primary and secondary radiologist because the left side was closer to the x-ray tube than the right side. After thermoluminescent dosimeters had been irradiated, the thermoluminescent dosimeters were then read out on the Harshaw 5500 automatic TLD reader. Then the factors corrected for sensitivity, energy response and charge to dose were applied.

The present study was undertaken on 42 patients of 23 TOCE[8], 9 PTBD[8] and 10 ERCP[8] covering a variety of both diagnostic and therapeutic procedures. The radiologists working in three rooms with different x-ray systems and radiation protection facilities, were monitored (Table 1). The data were collected for the first radiologist who stood about 0.6 meter from the patient and the second radiologist who was 1.2 meters from the patient.

At the same time, the doses as an indication of radiation dose to the patients were measured in terms of $cGycm^2$ for all patients by dose-area product (DAP)[9] which is shown in Fig. 2. DAP is a transmission ionization chamber (Diamentor E, PTW, Freiburg, Germany) fixed to the light beam diaphragm of the x-ray tube.

Table 1. The equipment used, lead protection available and kVp

Interventional suite	Protection available	Procedure	Installation	kVp
Siemens Polystar	Lead glass	TOCE, PTBD	1994	60-120
Siemens Neurostar	Mobile lead screen, Lead glass	TOCE, PTBD	1999	60-120
GE Advantx	None	ERCP	1992	60-120

Results and Discussion

1. Medical staff dose

The results of surface dose for first interventional radiologist in three procedures of three radiofluoroscopy machines are shown in Table 2. The left forearm was the site that showed the highest dose. The average surface dose values at the left forearm ranged from 174 to 407 µGy per procedure, depending on room, equipment, and experience of the radiologist. These results are agreeable with Vano E et al[1] who presented the values of 445 µGy per procedure at the left forearm.

These data were plotted as the histogram shown in Fig. 3. The dose to the left forearm from TOCE of Siemens Neurostar was higher than the left forearm dose of Siemens Polystar in the same procedure because the Siemens Neurostar beam quality, which is represented by HVL, is higher than Siemens Polystar. On the other hand, the dose to the left leg of medical staff work in Siemens Polystar was higher than Siemens Neurostar because there was no mobile lead screen against Siemens Polystar to protect the lower

Table 2. Values of dose per procedure for transarterial oily chemoembolization (TOCE) in Siemens Polystar, transarterial oily chemoembolization (TOCE) in Siemens Neurostar, percutaneous transhepatic biliary drainage (PTBD) in Siemens Polystar and endoscopic retrograde cholangiopancreatography (ERCP) in GE Advantx

TLD location	Sample size	Average (µSv)	Range (µSv)
TOCE (Siemens Polystar)			
Right eye	9	101	46-144
Left eye	9	102	23-150
Thyroid in thyroid shield	9	52	27-86
Thyroid out thyroid shield	9	74	27-128
Left shoulder	9	135	31-209
Left forearm	9	174	24-342
Gonad	9	35	9-76
Left leg	9	245	53-468
TOCE (Siemens Neurostar)			
Right eye	14	101	24-180
Left eye	14	159	5-355
Thyroid in thyroid shield	14	51	20-97
Thyroid out thyroid shield	14	151	7-288
Left shoulder	14	339	19-658
Left forearm	14	407	4-1211
Gonad	14	31	10-74
Left leg	14	32	10-67
PTBD (Siemens Polystar)			
Right eye	9	85	16-200
Left eye	9	110	23-282
Thyroid in thyroid shield	9	51	7-111
Thyroid out thyroid shield	9	63	1-200
Left shoulder	9	198	55-534
Left forearm	9	261	73-631
Gonad	9	25	2-48
Left leg	9	57	3-169
ERCP (GE Advantx)			
Right eye	-	-	-
Left eye	-	-	-
Thyroid in thyroid shield	10	170	98-318
Thyroid out thyroid shield	-	-	-
Left shoulder	10	246	123-476
Left forearm	10	352	111-755
Gonad	10	24	5-64
Left leg	10	287	64-888

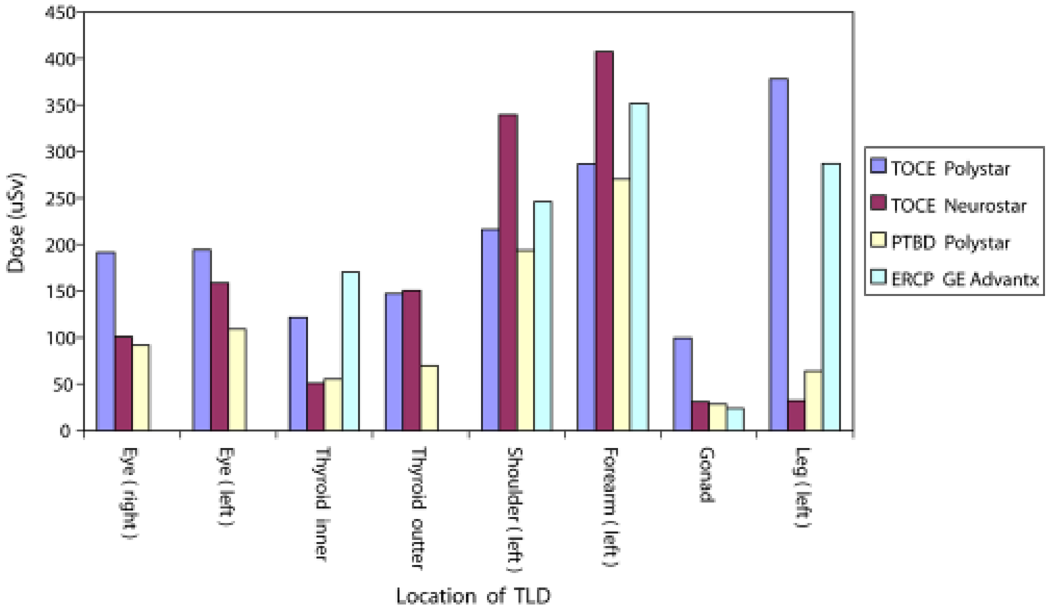

Fig. 3 Average doses to the radiologist in different locations

extremities of the medical staff but it was available at Siemens Neurostar. For PTBD and ERCP, the doses are quite low because the procedures were taken at a shorter time than TOCE.

The secondary radiologist received less surface dose than the primary radiologist. This is due to the fact that the distance from the primary radiologist to the beam was approximate by 0.6 meter, whereas for the secondary radiologist it was about 1 - 1.2 meters. The average, different dose between the primary and secondary radiologist is 52%; the result is statistically significant. ($p < 0.05$).

2. Dose-area product and the relationship with the dose to medical staff

The results of dose-area product measured during exposure to patients are shown in Table 3. The highest dose-area product reading is in TOCE. The dose-area product from TOCE from two x-ray machines is in the range 7,020-37,937 cGycm^2 for the fluoroscopy time of 6.07-29.20 minute.

A relation between occupational doses from TLD and patient doses evaluated from the dose-area product was established as shown in Table 4. For eight locations of the body, the highest ratio between average occupational doses and the dose-area product is the left forearm of PTBD and the lowest ratio is the gonad of ERCP. The dose received by radiologists when performing TOCE is low, because the radiologist was exposed to only scattered radiation from the fluoroscopy but not to the scatter from radiographic systems, they left the room during radiography. This makes the ratio between occupational doses and the dose-area product low, although the average dose from the

Table 3. Value of dose per procedure in interventional radiology, measured by dose-area product meter

Procedure	Sample size	Fluoroscopy time (min)	Dose-area product reading (cGy cm^2)	
			Range	Average
TOCE (Polystar)	9	6.07-28.50	13951-37937	19028
TOCE (Neurostar)	14	7.00-29.20	7020-33216	18025
PTBD	9	1.85-13.77	282-3270	1760
ERCP	10	1.70-23.00	958-10539	3504

Table 4. The ratio of averaged values between occupational doses and dose-area product in mSv/10 Gy cm^2 from thermo-luminescent dosimeter reading at eight locations on staff and from dose-area product

Location	TOCE (Polystar) n = 9	TOCE (Neurostar) n = 14	PTBD (Polystar) n = 9	ERCP (GE Advantx) n = 10
Right eye	5.31	5.60	48.29	-
Left eye	5.36	8.82	62.50	-
Thyroid in thyroid shield	2.73	2.83	29.98	48.02
Thyroid out thyroid shield	3.89	8.38	35.79	-
Left shoulder	7.09	18.81	112.50	70.21
Left forearm	9.15	22.58	148.29	100.46
Gonad	1.84	1.72	14.20	1.26
Left leg	12.88	1.78	32.39	81.91

dose-area product from TOCE is high.

It could be stated as a rule of thumb "a dose-area product reading of 10 $Gycm^2$ will give a dose of 10, 20, 150 and 100 µGy to the left forearm for TOCE of Siemens Neurostar, TOCE of Siemens Polystar, PTBD of Siemens Polystar and ERCP of GE Advantx, respectively". These relationships could provide a good reference for dosimetric control of staff, as demonstrated recently by Williams(2).

3. Summary of staff doses

The annual interventional radiology staff doses(14,15) are summarized in Table 5. The dose report for each procedure is less than the dose limit but if one radiologist performed all the procedures, the total dose at the left forearm would be 221.17 mGy per year. Although this is lower than the dose limit (500 mGy), one radiologist performed more than three procedures. Then the occupational dose may be over the dose limit. The availability and regular use of protective tools such as aprons, glasses, gloves, and screens should reduce the dose below the limit. Image quality control must be carried out on a regularly scheduled basis. Practices based on performing the procedures at the most suitable location with reference to the patient, with well collimated beams, using magnification only when strictly needed and low cine frame rates should be recognized as critical to radiation protection optimization strategies.

Conclusion

The present results show an ample range of variation in occupational doses at all the locations monitored on the staff. This confirms the influence of equipment features, the nature of the procedure carried out, and the source to image distance, fluoroscopy time, and distance from the scattering area on the patient.

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ปริมาณรังสีที่บุคลากรทางการแพทย์ได้รับในงานบริการทางรังสีร่วมรักษา

สรจรส อุณห์ศิริ, โชติกา จำปาเงิน, ทวีป แสงแห่งธรรม, อัญชลี กฤษณจินดา, ศิวลี สุริยาปี

วัตถุประสงค์: *การศึกษาครั้งนี้เป็นการวัดปริมาณรังสีที่ผิวของแพทย์ ในระหว่างการปฏิบัติงานรังสีร่วมรักษา โดยใช้เครื่องวัดรังสีชนิดเทอร์โมลูมิเนสเซนต์ รวมทั้งเป็นการหาความสัมพันธ์ระหว่างปริมาณรังสีที่ผิวของแพทย์ได้รับ กับปริมาณรังสีที่ผู้ป่วยได้รับซึ่งวัดได้โดยใช้เครื่องแดพมิเตอร์*

วัสดุและวิธีการ: *การศึกษาครั้งนี้ได้ทำการเก็บข้อมูลทั้งหมดจากผู้ป่วย 42 ราย ใน 3 ลักษณะงานบริการทางรังสีร่วมรักษา และใช้เครื่องเอกซเรย์ 3 เครื่อง เครื่องวัดรังสีดังกล่าวจะติดที่บริเวณผิวของแพทย์ ทั้งหมด 8 ตำแหน่งต่อคน ปริมาณรังสีที่ผู้ป่วยได้รับวัดจากเครื่องแดพมิเตอร์ ซึ่งติดกับคอลลิเมเตอร์ของหลอดเอกซเรย์ และได้ศึกษาความสัมพันธ์ของปริมาณรังสีที่แพทย์ได้รับที่ผิวกับปริมาณรังสีที่ผู้ป่วยได้รับ*

ผลการศึกษา: *ปริมาณรังสีที่ผิวสูงสุดที่แขนซ้ายของแพทย์มีค่า 407 ไมโครซีเวิร์ต อัตราส่วนระหว่างปริมาณรังสีสูงสุดที่ผิวของแพทย์ได้รับต่อปริมาณรังสีที่ผู้ป่วยได้รับ คือ 12.88, 22.58, 148.29 และ 100.46ไมโครซีเวิร์ต ต่อ 10 เกรย์ตารางเซนติเมตร จากการตรวจ TOCE (Siemens Polystar), TOCE (Siemens Neurostar), PTBD (Siemens Polystar) และ ERCP (GE Advantx) ตามลำดับ*

สรุป: *เมื่อสร้างความสัมพันธ์ระหว่างปริมาณรังสีที่ผิวของแขนแพทย์ได้รับกับปริมาณรังสีที่ผู้ป่วยได้รับจะได้ความสัมพันธ์แบบเส้นตรง ซึ่งจะช่วยให้แพทย์ทราบถึงปริมาณรังสีพึงได้รับเพื่อหลีกเลี่ยงการ ได้รับปริมาณรังสีสูง*