PATIENT SKIN DOSE MEASUREMENT IN CARDIAC CATHETERIZATION AND INTERVENTIONAL RADIOLOGY

KRISANACHINDA A,[1] KUMKRUA C,[1] WANGSUPHACHART S[1]

ABSTRACT

Objective: To determine the skin dose received by the patients who underwent cardiac catheterization and interventional radiology.

Methods: The patient skin dose in this study was determined by radiochromic film and Dose Area Product (DAP) methods. The dose measurement was carried out in 64 adult patients who underwent the interventional radiology examinations such as transarterial oily chemo embolization (TOCE), percutaneous transhepatic biliary drainage (PTBD), neurovascular intervention/angiography and percutaneous transluminal coronary angioplasty/stent (PTCA) at King Chulalongkorn Memorial Hospital. The maximum entrance skin dose from each case was determined by scanning radiochromic film to get the maximum density area on the film. This area represented the maximum entrance dose. However, the comparison of the radiochromic film and DAP were made to assess the patient skin dose and the maximum radiation dose from each procedure.

Results: The maximum skin dose from transarterial oily chemo embolization (TOCE) was 365 cGy, percutaneous transhepatic biliary drainage (PTBD) was 183 cGy, percutaneous transluminal coronary angioplasty/stent (PTCA) was 294 cGy, neurovascular interventional was 180 cGy and neurovascular angiography was 110 cGy. The patient skin dose in these studies depend on the length of fluoroscopy time and only one patient who reached the threshold dose of skin injury of 300 cGy. The maximum skin dose assessment from radiochromic film was compared with DAP calculation and showed the agreement, but radiochromic film showed higher radiation dose, because the calculated dose from DAP was the accumulated skin dose at different area and it was not the point entrance area of the patient.

Conclusions: There was only 1 incident where maximum skin dose exceeded the threshold dose for temporary epilation. The determination of the radiation dose in interventional radiology and cardiac catheterization is a benefit for the prevention of radiation skin injury and also increase the awareness of the radiologist and cardiologist in using the radiation for interventional procedures.

[1] Department of Radiology, Faculty of Medicine, Chulalongkorn University, Bangkok Thailand

INTRODUCTION

An increasing number of invasive procedures, primarily therapeutic in nature and involving uses of devices under fluoroscopic guidance, are becoming accepted in medical practice. Examples of such procedures are Percutaneous Transluminal Coronary Angioplasty/Stent (PTCA), neurointerventional radiology and catheter-based hepatobiliary interventional procedures including transarterial oily chemoembolization (TOCE) and percutaneous transhepatic biliary drainage (PTBD). These procedures are performed by a variety of medical specialists and may provide significant advantages over alternative therapies in terms of improved clinical outcome and reduced overall patient risks. However, physicians performed these procedures should be aware of the potential for serious radiation-induced skin injury caused by long periods of fluoroscopy occurring with some of these procedures. Such injuries have recently been reported as a result of radiation exposure during some of these procedures due to long fluoroscopic exposure times, high dose rates or both.

The radiochromic film known as Gafchromic film in this study was long widely used as a patient radiation dose detector.[1] It was applied to determine the doses in radiation therapy for many regions of the body i.e. breast.[2] The Gafchromic film was used in some study to measure the dose distribution in water in comparison to a solid phantom.[3] Some study showed the sensitivity of the Gafchromic film[4] and the application in radiation therapy. The Gafchromic film used in this study is the new type that develop for low dose detection for diagnostic purposes.

The other method for patient dose assessment is the use of Dose Area Product (DAP) meter, which the detector will be placed on the housing of the x-ray tube. The read out data from DAP meter in cGy.cm^2 and the radiation area in cm^2 from the verification film is calculated to determine the patient skin dose (cGy). The clinical research conducted at the cardiac center and the section of vascular & interventional radiology at King Chulalongkorn Memorial Hospital where the clinical service on cardiac catheterization such as PTCA, neurointerventional radiology and catheter-based hepatobiliary interventional procedures including TOCE and PTBD have been routinely performed and employs fluoroscopy.

In this study the Gafchromic film was used to determine the maximum entrance dose, DAP method was used to determine the total radiation dose of each procedure. Using both data from Gafchromic film and DAP method to determine and calculate the patient skin dose.[5]

EQUIPMENT AND ACCESSORIES

1 Gafchromic XR Type R Film (Model 37-046)

Gafchromic XR Type R is a self-developing radiochromic film. The film has white opaque at one side and yellow on the other side. The color of the yellow side will be changed to green color and darker as proportional to the amount of radiation doses in the range of 0.2 - 15 Gy.[6] The film is not energy dependent between 60 keV-120 keV, outstanding uniformity, dose rate and fractionation independent. This film type is designed and can be used to improve fluoroscopic technique and patient safety.[5,7]

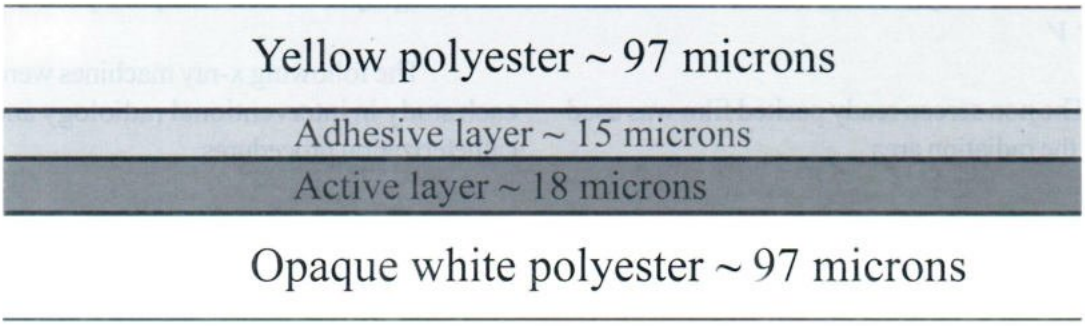

Fig.1 Configuration of Gafchromic XR Type R film

2 Dose Area Product (DAP) Meter (MODEL PTW-Diamentor E)

Dose-Area-Product (DAP) meter is large -area, transmission ionization chamber and associated electronics. In use, the ionization chamber is placed perpendicular to the beam central axis and in a location to completely intercept the entire area of the x-ray beam and the meter is placed at the control area. The DAP, in combination with information on x-ray field size (FOV) can be used to determine the average dose produced by the x-ray beam at any distance downstream in the x-ray beam from the location of the ionization chamber.

DAP meter is used to measure the absorbed dose (cGy), times the area of the x-ray field (cm^2), on patient skin. The relationship between DAP and exposure-area product (EAP) is essentially a single conversion factor that relates dose to exposure. EAP is expressed in roentgen-cm^2 (R-cm^2) and DAP is expressed in gray-cm^2 (Gy-cm^2,usually read in cGy -cm^2). The reading from a DAP meter is affected by the exposure factors (kVp, mA, or time), the area of the field (FOV), or both. The chamber area must be larger than that of the collimators, as the collimation blades are opened or closed, the charge collected will also increase or decrease in proportion to the area of the field.

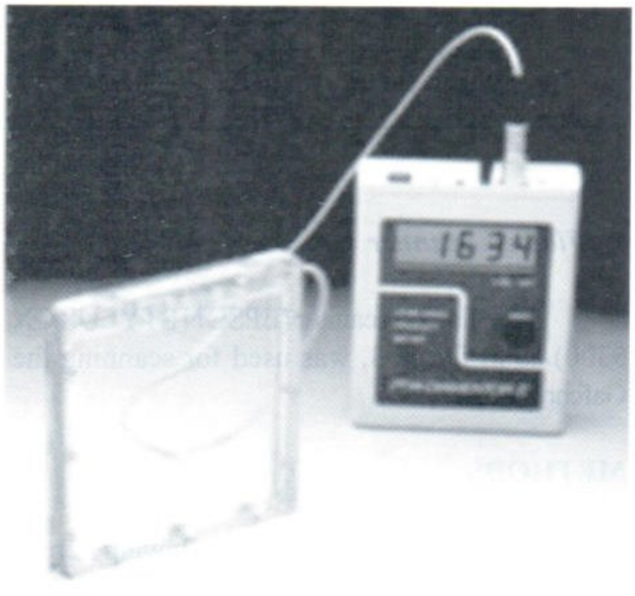

Fig.2 DAP meter and the Ion Chamber

3.Portal Film (Verification Film) Kodak Model X-Omat V

The non screen ready packed film was used to verify the radiation area.

4. Radiographic/Fluoroscopic System

The following x-ray machines were used for each study in interventional radiology and cardiac catheterization procedures.

Table 1 The equipment used for each procedure.

Procedures	Manufacturer	Model
1. Abdominal Interventional Radiology		
1.1. Transarterial Oily Chemoembolization (TOCE)	Siemens	Polystar
1.2. Percutaneous Transhepatic Biliary Drainage (PTBD)		
2. Neurovascular Interventional Radiology	Siemens	Neurostar
3. Percutaneous Transluminal Coronary	Siemens	Coroskop
Angioplasty / Stent (PTCA)	Siemens	Axiom

5. Flatbed Scanner

The flatbed scanner (EPSON STYLUS CX 5300) as in figure 3, was used for scanning the Gafchromic film.[5,7]

Fig.3 Flatbed scanner

METHODS

The study was carried on as these following steps.

1. The evaluation of radiographic-fluoroscopic system performance.[8,9]
2. The calibration of Gafchromic film and DAP meter.
3. The patient data collection using Gafchromic film and DAP meter methods.
4. The analysis of the data.
5. The evaluation of the patient skin dose.

RESULT

Table 2 The results of the clinical study showing the maximum skin dose measured by Gafchromic film and the skin area dose measured by DAP meter

Studies	x-ray tube	No.of cases	Age (Years)	Skin Dose from GF (cGy)	Radiation Area (cm2)		Flu Time (min)		DAP (cGy.cm2)	
				Max	Max	Min	Max	Min	Max	Min
TOCE		21	36-72	365	431	52	48	2.4	38,168	2,433
PTBD		5	17-87	183	186	82	15.03	1.51	5,972	520
Neuro	A			165	260	153	46	3.7	26,378	2,689
	B			165	285	153	21		16,825	1,176
	Total	22	17-61	180	285	153	46	3.7	36,221	3,865
PTCA		16	42-79	294	135	36	17.2	0.8	20,000	3,050
Total		64								

Fig 4: Maximum Skin Dose of Each Procedure

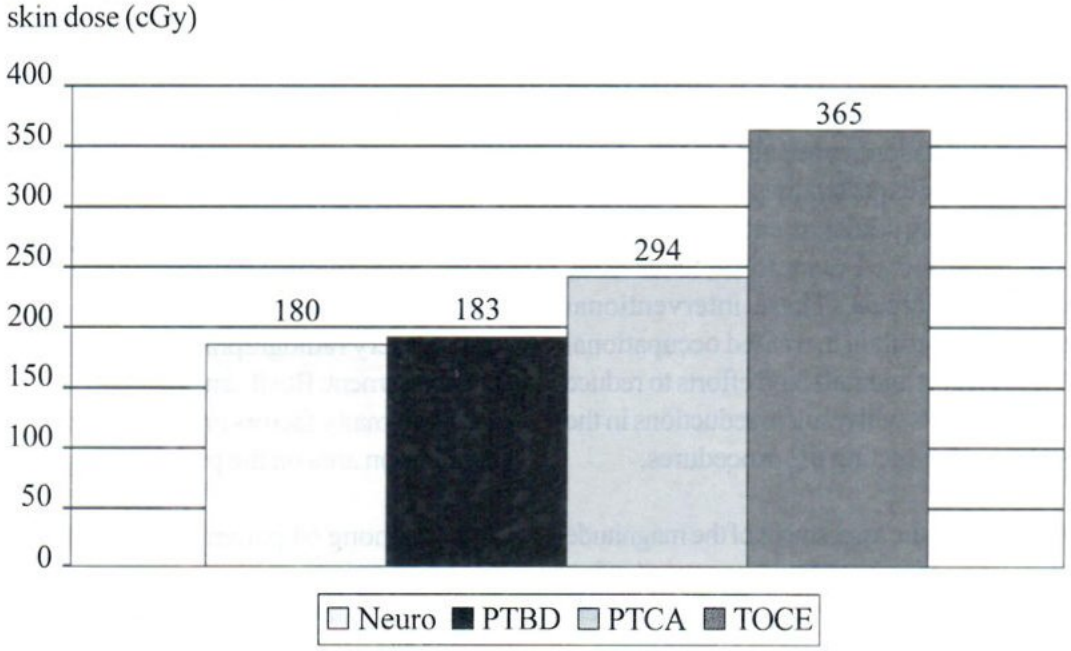

Fig.4 shows the results of the study as the data in the table 2 performed on 64 patients, the maximum skin dose was recorded from the TOCE procedure as 365 cGy, PTCA procedure 294 cGy. The longest of fluoroscopic time, 48 minutes was recorded from the TOCE procedure.

DISCUSSION

The result shows the linear correlation between the estimated dose from DAP meter and the maximum skin dose from Gafchromic film. There are several factors affected the dose estimation by the DAP meter such as the variation of the radiation field, the angle of the x-ray tube, varying the x-ray shutter during fluoroscopy, those made uncertain area for dose estimation.

The maximum skin dose determined by Gafchromic film of each procedure is higher than the estimated dose from DAP meter. Because the DAP is the cumulative dose from every exposure to parts of the patient, so the dose could be estimated from the averaged radiation areas, while maximum dose measured at one point on exposed skin. Both results compliment to each other and benefit the patient except the maximum exceeds the threshold level of skin injury.

Interventional radiology and cardiac catheterization procedures may increase the risk for late effects such as radiation-induced skin injuries. The potential for such late effects should not be disregarded in risk/benefit considerations, especially for individuals with many decades of expected life remaining, such as pediatric and young adult patients, or for procedures involving absorbed dose to radiosensitive tissues such as the breast. These interventional procedures can also result in increased occupational exposure to physicians and staff, and efforts to reduce the exposure to patients will result in reductions in the exposure to those conducting the procedures.

Complicating the assessment of the magnitude of the problem of injuries from fluoroscopy is the fact that the injuries are not immediately apparent. Typical times to onset or appearance of the effect may appear at variable period. The mildest symptoms, such as transient erythema, the effects of the radiation may not appear until weeks following the exposure. Physician performing these procedures may not be in direct contact with the patients following the procedure and may not observe the symptoms when they occur. Missing the milder symptoms in some patients can lead to surprise at the magnitude of the absorbed doses delivered to the skin of other patients when more serious symptoms appear. For this reason, it is recommended that information be recorded in the patient's record which permits estimation of the absorbed dose to the skin. Conside- ration should be given to counseling such patients on the possible symptoms and risks from those procedures.

CONCLUSION

The Gafchromic film detector has adequately measured maximum skin dose during fluoroscopic procedure for the interventional radiology and cardiac catheterization.[5,7] It can provide information for point dose assessment or profile measurements of dose if required but the relative expense of the film is a main obstacle.

The DAP meter is convenience instrument for radiation dose estimation and it generally should be built in every radiographic-fluoroscopic system for dose assessment. But it can be over or under estimated caused by many factors and the difficulty in located the radiation area on the patient.

Among 64 patients, there is 1 of the patient who has maximum skin dose exceed the threshold dose for temporary epilation[5] as shown in Table 3

Table 3 Radiation induced skin injuries

Effect	Typical Threshold Absorbed Dose (Gy)*	Hours of Fluoroscopic "On Time" to reach threshold+ at:		Time to Onset of Effect++
		Usual Fluoro. Dose Rate of 0.02 Gy/min (2 rad/min)	High-Level Dose Rate of 0.2 Gy/min (20 rad/min)	
Early transient erythema	2	1.7	0.17	Hours
Temporary epilation	3	2.5	0.25	3 wk
Main erythema	6	5.0	0.50	10 d
Permanent epilation	7	5.8	0.58	3 wk
Dry desquamation	10	8.3	0.83	4 wk
Invasive fibrosis	10	8.3	0.83	
Dermal atrophy	11	9.2	0.92	>14 wk
Telangiectasis	12	10.0	1.00	>52 wk
Moist desquamation	15	12.5	1.25	4 wk
Late erythema	15	12.5	1.25	6-10 wk
Dermal necrosis	18	15.0	1.50	>10 wk
Secondary ulceration	20	16.7	1.67	>6 wk

* The unit for absorbed dose is the gray (Gy) in the International System of units. One Gy is equivalent to 100 rad in the traditional system of radiation units.

\+ Time required to deliver the typical threshold dose at the specified dose rate.

++ Time after single irradiation to observation of effect.

The determination of the radiation dose in the interventional radiology and cardiac catheterization is valuable for radiation injury prevention and also increase the awareness of the radiologist and cardiologist.

The result can be used as a guideline for studying the dose range of each procedure (Table 2) in order to optimize the exposure technique and the dose limit.

REFERENCES

1. Butson M J, Mathur J N, and Metcalfe P E. Radiochromic film as a radiotherapy surface dose detector. Phys Med Biol 46,1996; 235-240.
2. Cheung T, Butson M J, and Yu P K N. Multilayer Gafchromic film detectors for breast skin dose determination in vivo. Phys Med Biol 47, 2002; 31-37.
3. Butson M J, Cheung T, and Yu P K N. Radiochromic film dosimetry in water phantoms. Phys Med Biol 46, 2001; 27-31.
4. Butson M J, Cheung T, and Yu P K N. Corresponding dose response of radiographic film with layered Gafchromic film. Phys Med Biol 47, 2002; 285-289.
5. Food and Drug Administration, "Important Information for Physicians and Other Health Care Professionals" Recording Information in the Patient's Medical Record that Identifies the Potential for Serious X-Ray Induced Skin Injuries Following Fluoroscopically Guided Procedures, September15th, 1995.
6. Fajardo LC, Geise RA, Ritenour ER. A survey of films for use as dosimeters in interventional radiology. Health Phys 68, 1995; 595-599.
7. Thomas G, Chu RY, and Rabe F. A study of Gafchromic XR Type R film response with reflective-type densitometers and economical flatbed scanners. Appl Clin Med Phys.4, 2003; 307-314.
8. American Association of Physicists in Medicine, Managing the use of fluoroscopy in medical institutions, AAPM Report No. 58, 1998; 1 37.
9. Shope TB. "Regulations and recommendations relevant to interventional radiology" in Syllabus: categorical course in physics: physical and technical aspects of angiography and interventional radiology (Oak Brook, Radiological Society of North America, 1995; 195-205.