Original Article

Patient Skin Dose in Interventional Radiology, TOCE at Songklanagarind Hospital

Anchali Krisanachinda, Ph.D.[1]
Prasert Wattanapongpitak, B.Sc.[2], **Panomporn Vimuttisuk, B.Sc.**[2]

[1] *Department of Radiology, Faculty of Medicine, Chulalongkorn University*

[2] *Department of Radiology, Faculty of Medicine, Prince of Songklanagarind University*

Abstract

The purpose of this study is to determine the patient skin dose for Transarterial Oil Chemo Embolization (TOCE) procedure and the factors affecting in this study. Dose Area Product (DAP) meter was used to measure the patient skin dose in terms of Gy.m^2. After applying the exposed area on the imaging plate placed on patient's couch, the skin dose, mGy, can be determined. Twenty-nine hepato-cellular carcinoma (HCC) patients underwent TOCE procedure at Songklanakarind Hospital were carried out for interventional radiology procedures in the period of July-September 2008. The average skin dose is 0.428 Gy, the maximum dose is 1.249 Gy and the minimum dose is 0.176 Gy.

As the exposed area on the imaging plate is mostly invariable, the patient skin dose is directly dependent on the DAP readout with the correlation coefficient, r^2 of 0.97 while the correlation coefficient with body mass index is 0.102 and the correlation coefficient with the fluoroscopy time is 0.22. The maximum skin dose is lower than the threshold limit of erythema dose of 2 Gy.

Introduction

The use of ionizing radiation for fluoroscopically guided interventions introduces two principal types of risks during medical care. The first is the stochastic risk of induced neoplasia and the second is deterministic risks for effects in superficial tissues such as the skin or the lens of the eyes. A third stochastic risk associated with ionizing radiation is that of heritable genetic risks passed on to descendants. This risk applies only to patients who will parent future offspring. Therefore, the risk associated with the use of ionizing radiation to treat patients with an urgent demand in medical needs deserve considerations. The aspect of assessing risk of ionizing radiation in relation an individual patient versus the anticipated benefits should be considered.

Since 1990, hundreds of reports on radiation skin injury from fluoroscopic interventions have been published.[1-4] To reduce the likelihood adverse radiation effects, the intervention radiologists must be well trained in the methods to conserve radiation use; the fluoroscopic equipment must be appropriately designed and well maintained for high quality imaging at low radiation output. The purpose of this project is to assess the potential for conserving radiation use by studying circumstances of procedures performed at Songlanakarind Hospital. Therefore, the project was designed to utilize the dosimetry techniques such as dose area product (DAP) to assess patient doses. The ultimate goal is to evaluate the role of different factors in patient dose management.

Dose Monitoring

Dose-area-product meters are wide-area output detectors that can only assess the average dose over the radiation beam area. Readout is provided in units of $Gy.m^2$. The device provides no assessment of dose to the skin. To obtain an estimate of skin dose, the area of the beam at the skin surface must be known. This should be useful in which the beam seldom changes either in size or in angulations.

Materials

1. X-ray system. Manufacturer Philips Medical System Model Integress V5000 (Fig 1)
2. DAP Meter Manufacturer PTW Model Pehamed W2 (Fig 2)
3. Imaging plate. Manufacturer Fuji Model ST-VI size 14x17 inch (Fig 3)
4. CR Reader Manufacturer Fuji Model FCR XG 5000
5. Ionization chamber and Electrometer Manufacturer RADCAL Model 9095
6. Workstation Manufacturer Rogan Version 2.0

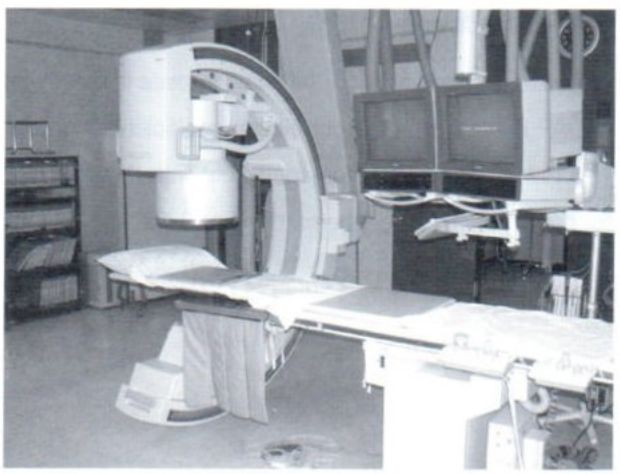

Fig.1 Radiographic Fluoroscopic System for TOCE Procedures

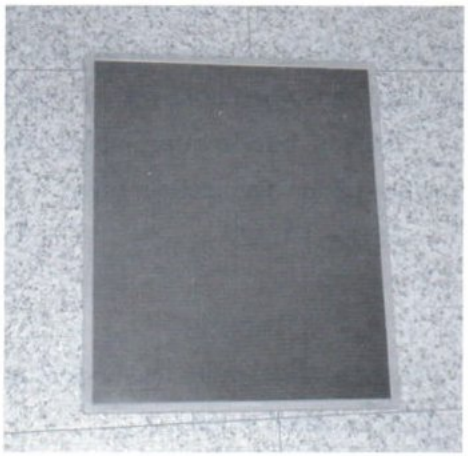

Fig.2 CR Imaging Plate Fuji Model ST-VI

Fig.3 DAP detector and Meter PTW Model Pehamed W 2

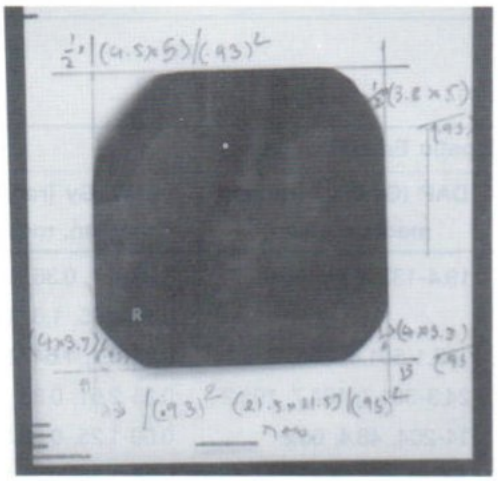

Fig.4 Fluoroscopic Exposed area during TOCE on film

Methods

1. Perform the quality control of the radiographic-fluoroscopic system using IAEA and AAPM protocols for

- Radiation dose assessment
- Automatic Brightness Control (ABC)
- Maximum dose rate assessment
- Table attenuation determination
- Image size assessment
- Half Value Layer assessment
- Image quality assessment

2. Calibrate DAP with Ionization chamber as in figure 5 to obtain DAP calibration factors.

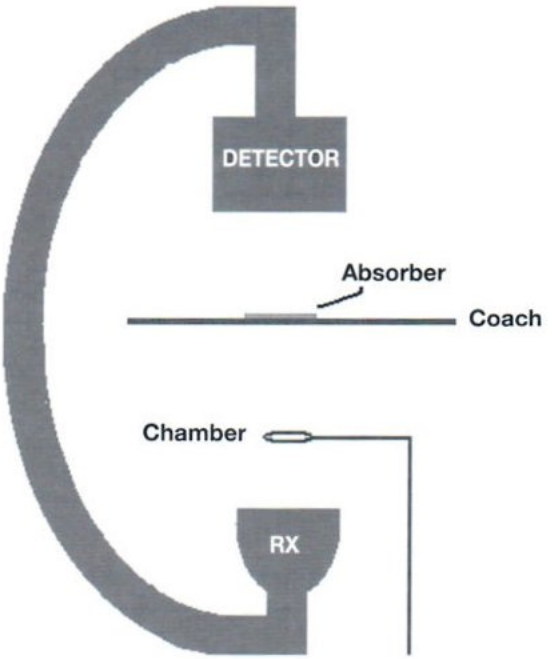

Fig.5 DAP and Ionization Chamber setup to obtain the DAP calibration factor

3. Patient data collection:

- H.N.
- Age, weight, height, sex

4. Patient dose determination

- Place the DAP detector on the x-ray collimator securely.
- Place the imaging plate on the patient's couch and under the patient back at the liver region
- Record the following parameters: kVp, mAs, SID, SSD, fluoroscopic time, DAP cumulative dose, radiologists experience, complexity index.
- Determine the exposed area, m^2 from exposed film.
- Calculate the patient entrance skin dose, ESD

$$ESD = f(E) \times BSF \times AK$$

f(E) is the f-factor that converts air-kerma (AK) into absorbed skin dose is usually 1.06 mGy tissue absorbed dose per mGy air-kerma

BSF is backscatter factor which is approximately 1.3 for diagnostic x-rays

$$ESD = 1.4\ AK$$

Results

1. Patient characteristics. Number of patients is 29 as detail in table 1.
2. Measured and collected items are shown in table 2.
3. Other reports are shown in table 3

Table 1 Twenty-nine HCC patients who underwent TOCE at Songklanagarind Hospital

Sex		Age (years)			Weight (kg)			Height (cm)			BMI ($kg.m^{-2}$)		
Male	Female	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
24	5	62.3	39	82	57.7	38	73.4	165.9	151	180	20.98	16.67	22.65

Table 2 Parameters collected at the end of TOCE procedures

Fluoroscopy Time (minutes)			DAP ($Gy.cm^2$)			Area (m^2)			ESD (Gy)		
Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
17.91	6.5	55.4	19.60	7.67	61.32	0.05	0.04	0.07	0.428	0.176	1.249

Table 3 Factors influenced the patient skin dose from other countries.

Country	Hepatic Embolization			
	No.of patients	Fluoroscopy Time (min) (range, median, mean)	DAP ($Gy.cm^2$) (range, median, mean)	ESD, Gy (range, median, mean)
India	16	2.7-36.5, 20.0, 18.4	19.4-133, 63.6, 65.0	0.03-0.7, 0.36, 0.34
Japan	19	3.6-62.9, 24.6, 30.4	-	0.16-2.95, 1.6, 1.47
Malaysia	6	15.4-59.9, 42,38.3	157.1-501.4, 265, 288.1	0.68-3.1, 1.64, 1.77
Thailand*	30	2.4-48.0, 9.2, 14.7	24.3-381.7, 184.7, 195.2	0.25-2.61, 0.88, 1.06
Turkey	15	1.8-12.9, 8.7,7.7	14-204, 48.4, 65.2	0.09-1.25, 0.32,0.43
This Study	29	6.5-55.4, 16.4, 17.9	7.7-61.3, 17.3,19.6	0.18-1.25, 0.38,0.43

*King Chulalongkorn Memorial Hospital

Discussion

Data were acquired for a wide variety of hepatic embolization procedures resulted in wide variations in fluoroscopy times, 6.5-55.4 minutes, DAP readout, 7.7-61.6 Gy.cm^2 and mean skin dose (MSD), 0.18-1.25 Gy, among twenty-nine patients. While the relationship of DAP to BMI appears to be linear, the data are few and no substantive conclusion should be drawn. There is a mild influence of BMI on skin dose to patients, suggesting that factors other than BMI are more important in predicting the final dose result. The patient with maximum BMI of 26.84 kg/m^2 obtained the skin dose of 0.175 Gy while the patient with lowest BMI of 15.22 kg/ m^2 obtained the skin dose of 1.248 Gy. None of the data suggest the significant correlation between maximum skin dose and body mass index as in Figure 6. (R^2 =-0.1016)

Both ESD and DAP tend to increase with increasing fluoroscopy time in a linear way for hepatic embolization procedures as in figure 8.

Figure 8 demonstrates that the use of DAP to predict skin dose for hepatic procedures must be approached with caution. Generally, a linear relationship between ESD and DAP exist as in figure 7. A consistent behavior in use of beam orientation, geometry, and machine setting is likely to result in tight variation around a linear trend line. Consistency in execution is the key to making DAP a useful tool to estimate skin dose.

High skin dose

The patient high skin dose during TOCE procedures could be of multiple explanations such as the fluoroscopic time, DAP values, kVp. In this study, the maximum time is 55.4 minutes while other study in Table 3 showed the longest time of 62.9 minutes and the maximum skin dose of 2.95 Gy. The DAP value showed the range of 7.7-61.3 Gy.cm^2 which is less than other study ranged up to 501.4

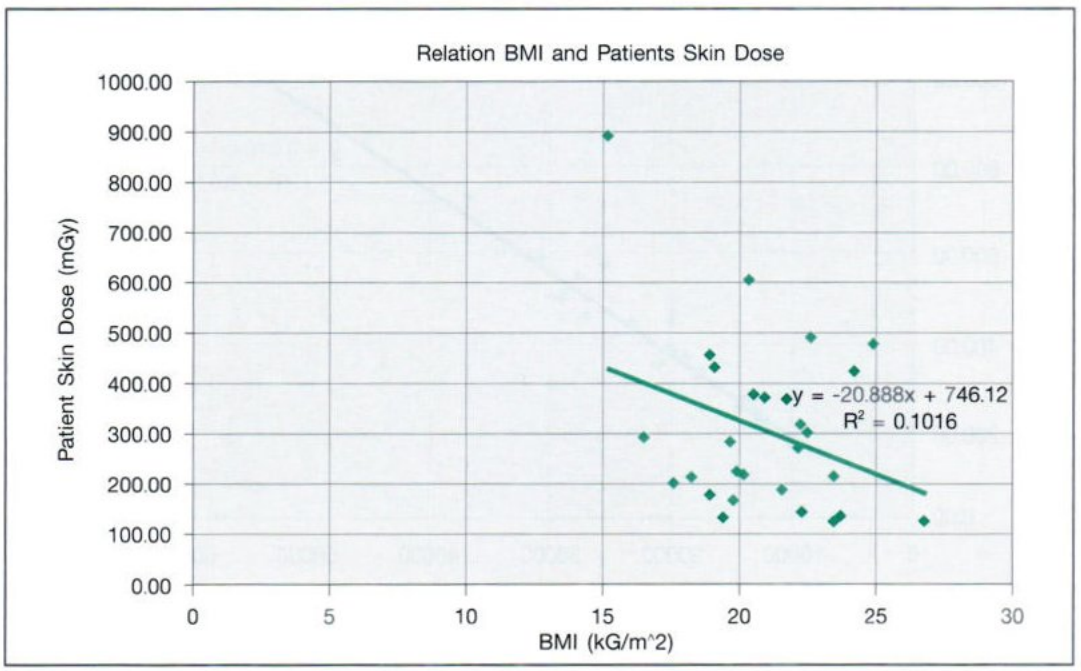

Fig.6 The poor correlation between the patient skin dose and BMI, body mass index

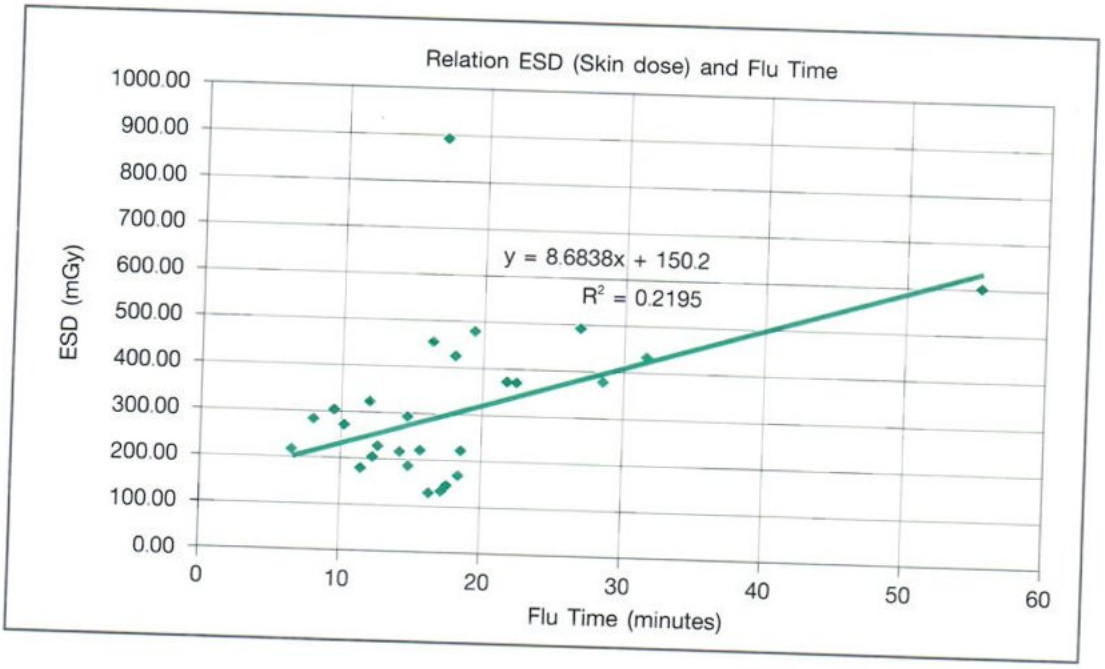

Fig.7 The linear correlation between the patient skin dose (ESD, mGy) and the fluoroscopic time (minutes)

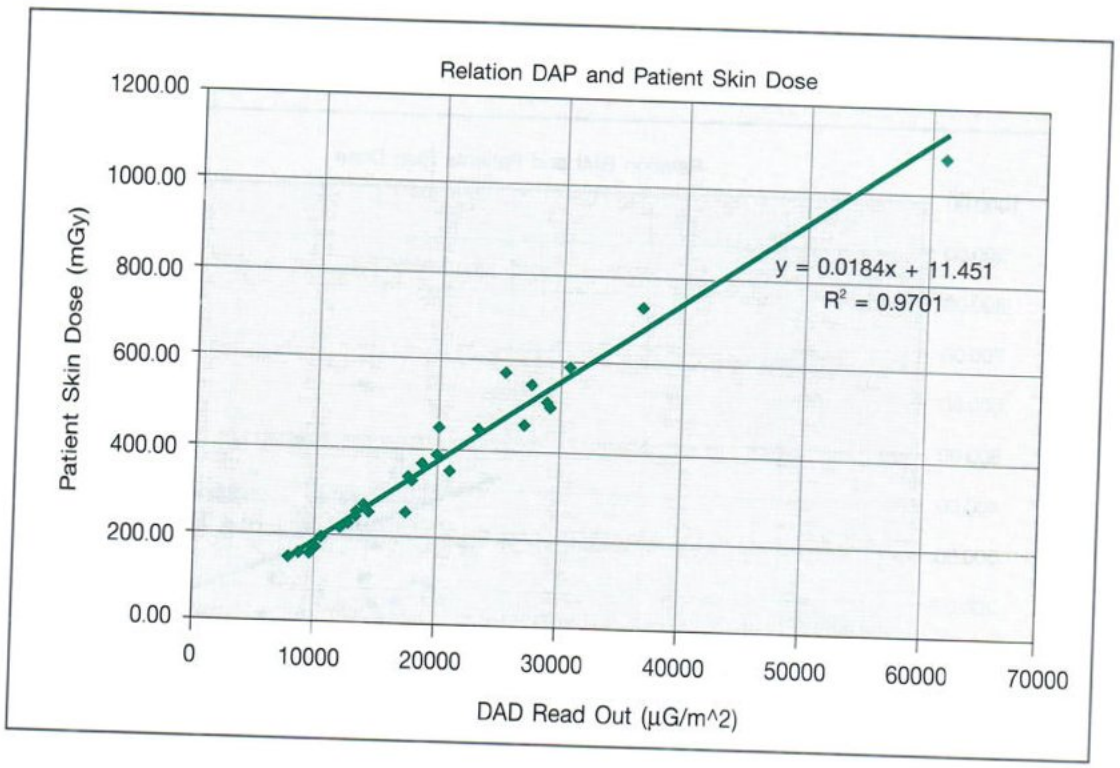

Fig.8 The linear correlation coefficient between the DAP and ESD of $r^2 = 0.97$

$Gy.cm^2$ causing the skin dose of 3.1 Gy. For maximum kVp, this study used 84 and the average of 75.38 resulting in moderate skin dose compared to the kVp reach above 100 and for high magnification modes for other study. The exposure dose rate could be as high as four times for magnification mode when compared to normal mode. Some physicians did not use collimation very often and this resulted in overlap of fields when the beams were changed to a different orientation. Without overlap, the maximum skin dose would have been much lower. These are likely related to experience and training. The machine pulse rate modes, the automatic exposure rate are parameters influenced the high skin dose if the physicians did not use appropriately.

Conclusion

Radiation risks. Radiation induced cancer is a long term risk of about one incidence per 1,000 patients receiving DAP of 80 $Gy.cm^2$ at the age of 60. It is about 4 times this amount for the same DAP in a patient of age 10 years. Radiation injury has occurred in patients undergoing complex interventional procedures, many have been severe. A mild radiation injury occurred in the skin of patient during this study. Severe effects are rare in relation to the number of procedures performed.

Dose management. Body mass index is the weak related risk for high skin dose in the interventional procedures. This means that the patient size is far less an important predictor of the dose to be delivered than other factors such as complexity or difficulty of the procedure. A large patient will contribute to the elevation of a high dose delivery during a complex and difficult procedure.

Radiation dose monitoring to patients with sufficient accuracy required the available resources to assure the quality result. However, monitoring patient skin dose to manage near-term adverse effects is important for patient care. Fluoroscopy time is correlated with dose to the patient but is a poor predictor of it because it does not account for the effects of image acquisition modes, different beam geometry and output modes of operation. Table 3 shows DAP readout is more significantly correlated with skin dose than fluoroscopy time. Under careful application and certain circumstances, maximum skin dose may be estimated from DAP. Experience of the interventionist in efficiently completing a procedure is a major factor in dose management. It was demonstrated that significant increases in dose to the patient result from interventionists who are less skilled than others.

Dose monitoring is a valuable tool. It is recommended to each facility establish a dose monitoring methodology suitable for the purpose. Action should be taken as doses exceed certain threshold levels.

References

1. Koenig TR, Wolff D, Mettler FA, Wagner LK. Skin injuries from fluoroscopically guided procedures: Part 1, Characteristics of radiation injury. AJR Am J Roentgenol 2001: 177;3-11
2. Koenig TR, Mettler FA, Wagner LK. Skin injuries from fluoroscopically guided procedures: Part 2, review of 73 cases and recommendations for minimizing dose delivered to the patient. AJR Am J Roentgenol 2001;177;13-20.
3. Shope TB. Radiation induced skin injuries from fluoroscopy. RadioGraphics 1996;16:1195-9.
4. Vlietstra RE, Wagner LK, Koenig TR, Mettler F. Radiation burns as a severe complication of fluoroscopically guided cardiological interventions. J Intervention Cardio 2004: 17;131-42.