EVALUATION OF PATIENT DOSE UNDERGOING INTERVENTIONAL RADIOLOGY AT RAMATHIBODI HOSPITAL

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EVALUATION OF PATIENT DOSE UNDERGOING INTERVENTIONAL RADIOLOGY AT RAMATHIBODI HOSPITAL

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ABSTRACT

This study was carried out to assess radiation doses in patients who underwent international radiology procedures at Ramathibodi hospital. Data were collected from 120 patients who underwent transarterial oily-chemoembolization (TOCE), femoral angiography, diagnostic and therapeutic cerebral angiography. A built-in Kerma Area Product (KAP) meter was calibrated in situ with a 6 cm^2 ionization chamber to find correction factors at tube voltages between 50 to 100 kVp. The calibration coefficient of the KAP meter was found to vary by ±5.07%, ±7.2 % and ±4.86 % from the calibration coefficients of 80 kV for a single-plane, tube 1 and tube 2 of the bi-plane x-ray system, respectively. Mean KAP values were 9099.41, 3101.87, 3310.97 (Frontal), 3500.68 (Lateral), 5014.75 (Frontal), 9731.47 (Lateral) $cGy\text{-}cm^2$ for TOCE, femoral angiography, diagnostic cerebral angiography, therapeutic cerebral angiography, respectively. The therapeutic cerebral angiography procedure was found to give the highest entrance dose at 3,626.28 mGy in the lateral view. However, the highest KAP value was from TOCE with 26,437.11 $cGycm^2$. There were 2 cases in therapeutic cerebral angiography with patient entrance doses higher than 3 Gy in the frontal view, which reached the deterministic threshold for temporary epilation. We found very wide variations in patient doses from different interventional procedures. There is a need for a dose record system to provide feedback to the radiologist who performed the procedure; especially those with a dose that exceeded the deterministic threshold.

KEY WORDS: RADIATION DOSE/PATIENT DOSE/KAP/ENTRANCE DOSE/INTERVENTIONAL RADIOLOGY

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การประเมินปริมาณรังสีที่ผู้ป่วยได้รับจากรังสีร่วมรักษาในโรงพยาบาลรามาธิบดี

EVALUATION OF PATIENT DOSE UNDERGOING INTERVENTIONAL RADIOLOGY AT RAMATHIBODI HOSPITAL

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คณะกรรมการที่ปรึกษาวิทยานิพนธ์: นภาพงษ์ พงษ์นภางค์, Ph.D, ศิรินธรา สิงหรา ณ อยุธยา, M.D.

การศึกษานี้เป็นการประเมินปริมาณรังสีที่ผู้ป่วยได้รับจากรังสีร่วมรักษาในโรงพยาบาลรามาธิบดี ข้อมูลที่ได้มาจากผู้ป่วย 120 คนที่ได้รับการตรวจหรือรักษาด้วยวิธี การรักษาเนื้องอกที่ตับโดยให้ยาเคมีบำบัดทางหลอดเลือดแดง, การตรวจเส้นเลือดแดงที่ขา, การตรวจและการรักษาเส้นเลือดบริเวณสมอง Kerma Area Product (KAP) meter ที่ติดตั้งกับเครื่องส่องตรวจทางรังสีจะถูกสอบเทียบภายในโดยใช้หัววัดรังสีขนาด 6 ลูกบาศก์เซนติเมตรเพื่อหาค่าแก้ในช่วงความต่างศักย์ของหลอดเอกซ์เรย์ระหว่าง 50 ถึง 100 kVp ค่าแก้มีค่าแกว่งอยู่ระหว่าง ±5.07%, ±7.2 %, ±4.86 % ของค่าแก้ที่ความต่างศักย์ของหลอดเอกซ์เรย์ 80 kVp สำหรับเครื่องเอกซ์เรย์หัวเดียว,หลอดเอกซ์เรย์ที่ 1 และ 2 ของเครื่องเอกซ์เรย์แบบ 2 หัวตามลำดับ ค่าเฉลี่ยของ KAP มีค่า 9099.41, 3101.87, 3310.97 (Frontal), 3500.68 (Lateral), 5014.75 (Frontal), 9731.47 (Lateral) $cGycm^2$ สำหรับการรักษาเนื้องอกที่ตับโดยให้ยาเคมีบำบัดทางหลอดเลือดแดง, การตรวจเส้นเลือดแดงที่ขา, การตรวจและการรักษาเส้นเลือดบริเวณสมองตามลำดับ การรักษาเส้นเลือดบริเวณสมองมีค่าปริมาณรังสีที่ทางเข้ามากที่สุดเท่ากับ 3,626.28 mGy ในการเอกซ์เรย์ด้านข้าง แต่อย่างไรก็ตาม ค่า KAP ที่มากที่สุดมาจากการรักษาเนื้องอกที่ตับโดยให้ยาเคมีบำบัดทางหลอดเลือดแดงมีค่า 26,437.11 $cGycm^2$ มี 2 การรักษาเส้นเลือดบริเวณสมองที่มีปริมาณรังสีที่ทางเข้ามากกว่า 3 Gy ในการเอกซ์เรย์ด้านหน้า-หลัง ซึ่งมีปริมาณรังสีมากพอที่จะเกิดผลชัดเจนของผิวหนังคือผมหรือขนร่วงชั่วคราว เราพบว่าปริมาณรังสีที่ผู้ป่วยได้รับมีการแปรปรวนมากในรังสีร่วมรักษาที่มีวิธีการต่างกัน ระบบบันทึกจึงเป็นสิ่งที่ต้องการเพื่อรายงานผลไปยังแพทย์ที่ทำการตรวจหรือรักษา โดยเฉพาะในรายที่ปริมาณรังสีถึงปริมาณรังสีขั้นต่ำที่จะทำให้เกิดเกิดผลชัดเจนได้

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LIST OF ABBREVIATIONS

Abbreviation	**Term**
ABC	Automatic brightness control
mA	Miliampere
mAs	Tube current
AV	Arteriovenous
AVM	Arteriovenous malformation
CA	Coronary angiography
CA-PT-SI	Coronary angiography and Percutaneous transluminal coronary angioplasty and stent implantation
CT	Computed Tomography
°C	Degree Celsius
DAP	Dose-Area Product
DAVF	Dural arteriovenous fistula
Diag	Diagnostic
DSA	Digital subtraction angiography
ESD	Entrance skin dose
ED	Entrance dose
et al.	et alibi
FSD	focal to skin distance
keV	Kiloelectronvolt
MeV	Megaelectronvolt
FDA	Food and Drug Administration
FOV	Field of View
Gy	Gray
mGy	Milligray
nGy	Nanogray
Gy/s	Gray per second

LIST OF ABBREVIATIONS (cont.)

mGy/s	Milligray per second
nGy/s	Nanogray per second
Gy/min	Gray per minute
Gym^2	Gray square meter
$Gycm^2$	Gray square centimeter
$cGycm^2$	Centigray square centimeter
$Gycm^2s^{-1}$	Gray square centimeter per second
HLV	Half-Value-layer
IAEA	International Atomic Energy Agency
In_2O_3:Sn	Indiumoxide doped with tin
J/kg	joule per kilogram
$Jkg^{-1}\cdot s^{-1}$	joule per kilogram second
$Jkg^{-1}\cdot m^2$	joule square meter per kilogram
KAP	Air Kerma-Area Product
cm^2	square centimeter
cm^3	cubic centimeter
min	minute
mm	Millimeter
mm^2	square millimeter
mmAl	Millimeter aluminium
NCRP	National Council on Radiation Protection and Measurements
PMMA	Polymethyl methacrylate
PTC	Percutaneous transhepatic cholangiography
PTCA	Percutaneous transluminal coronary angioplasty
PT-SI	Percutaneous transluminal coronary angioplasty and stent implantation
kPa	Kilopascal

LIST OF ABBREVIATIONS (cont.)

R/s	Roentgen per second
mR/s	Milliroentgen per second
R^2	The correlation coefficient
rad/min	rad per minute
SID	Source to image receptor distance
SSD	Source to skin distance
ms	millisecond
mSv	millisieverts
$mSvGy^{-1}cm^{-2}$	millisieverts per gray square centimeter
No.	number
TIPS	Transjugular intrahepatic portosystemic shunt
TOCE	Transarterial Oily-chemoembolization
Ther	Therapeutic
TLD	Thermoluminescent dosimeters
kV	kilovoltage
kVp	Peak kilovoltage
WHO	World Health Organization

CHAPTER I
INTRODUCTION

1.1 Introduction

In 2006, National Council on Radiation Protection and Measurements (NCRP) published a document entitled 'Ionizing Radiation Exposure of the Population of the United States' [20]. The report shows that radiation from human-made is 50 % of all radiation. From this human-made radiation, 36 % comes from Diagnostic Radiation, including 5 % from general X-ray and Fluoroscopy, 24 % from computed tomography (CT), 7 % from Interventional Radiology. It is clear that most radiation received by the population came from general Diagnostic Radiation. Interventional Radiology, though in a lesser extent of radiation delivery to the population, can give very high individual dose that can possibly reach the deterministic threshold.

Currently, interventional radiology procedure has been increasingly performed in numbers of pathological conditions. However, high radiation dose from lengthy procedures can harm the patients. The physicians concerns come from serious radiation-induced injury caused by high radiation skin dose or long time of fluoroscopy in some procedure. With such concerns, international or national organization such as World Health Organization (WHO) and German Institute for Radiation Hygiene [1] organized a workshop on efficacy and radiation safety in interventional radiology. Food and Drug Administration (FDA) published documents [2] on how to avoid deterministic effects in cardiology procedures. The absorbed dose in the patient's skin of 2 Gray (Gy) should raise concerns about onset of transient erythema and 3 Gy for temporary epilation. Information of the absorbed dose to skin should be included in the patient's records.

KAP (Air Kerma-Area Product) meter is a transmission ionization chamber that measure radiation dose in air. The data from KAP meter is expressed in $Gycm^2$ and KAP rate is express in $Gycm^2s^{-1}$. Numbers of investigators utilized the KAP values to assess radiation risk from fluoroscopic studies. [6,7] The KAP can indicate the risk better than the entrance skin dose due to the fact that the KAP is a product from entrance dose and field size. [3] This study was carried out to assess radiation dose to patients undergoing interventional radiology procedures at Ramathibodi Hospital, Bangkok, Thailand.

1.2 Background

1.2.1 Dosimetric quantity and units

The definition of Dosimetric quantity and units used in this study is definition from IAEA Technical Report Series no. 457.

1.2.1.1.Kerma

The kerma, K, is the quotient dE_{tr} by dm, where dE_{tr} is the sum of the initial kinetic energies of all the charged particles liberated by uncharged particles in a mass dm of material, thus:

$$K = \frac{dE_{tr}}{dm}$$

Unit: Jkg^{-1}. The special name for the unit of kerma is gray (Gy).

1.2.1.2.Kerma rate

The kerma rate,$\dot{K}$, is the quotient dK by dt, where dK is the increment of kerma in the time interval dt, thus:

$$\dot{K} = \frac{dK}{dt}$$

Unit: $Jkg^{-1}\cdot s^{-1}$. If the special name gray is used, the unit of kerma rate is gray per second (Gy/s).

1.2.1.3.Incident air kerma

The incident air kerma, K_i, is the kerma to air from an incident X-ray beam measured on the central beam axis at the position of the patient or phantom surface. Only the radiation incident on the patient or phantom and not the backscattered radiation is included.

Unit: Jkg^{-1}. The name for the unit of kerma is gray (Gy).

1.2.1.4.Entrance surface air kerma

The entrance surface air kerma, K_e, is the kerma to air measured on the central beam axis at the position of the patient or phantom surface. The radiation incident on the patient or phantom and the backscattered radiation are included.

$$K_e = K_i B$$

Unit: Jkg^{-1}. The name for the unit of kerma is gray (Gy).

1.2.1.5.Air kerma-area product

The air kerma–area product, P_{KA}, is the integral of the air kerma over the area of the X-ray beam in a plane perpendicular to the beam axis. The air kerma–area product is approximately invariant with distance from the X-ray tube focus, as long as the planes of measurement and calculation are not so close to the patient or phantom that there is a significant contribution from backscattered radiation.

$$P_{KA} = \int_A K(x, y)dxdy$$

Unit: $Jkg^{-1}\cdot m^2$. If the special name gray is used, the unit of air kerma–area product is Gym^2.

1.2.2 Radiation induce skin injury

The Radiation induced skin injury is related with cumulative of absorbed dose, it depends on dose rate, fractionation, organ, age and patient's size. The typical absorbed dose rate in skin from fluoroscopic system is between 0.02 to 0.05 Gy/min or 0.01 to 0.5 Gy/min depending on fluoroscopic mode, fluoroscopic system. In some fluoroscopic mode or large patient, the dose rate can be higher than normal case. The typical threshold absorbed dose, time required to deliver the threshold by continuous fluoroscopic X-ray dose rate of 0.02 Gy/min and 0.2 Gy/min is shown in Table 1.1

Table 1.1 The radiation induced skin injury [2]

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	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 to100 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.

1.2.3 Ionization chamber

Ionization chamber is a radiation detector, which function isbased on collection of all charges created by direct ionization within the gas. Ionization chamber composes of anode and cathode. The voltage applied between the anode and cathode to collect the charge produced in the gas by the ionizing radiation. The voltage between 100 to 300 Volts is high enough to collect the producing charge but not so high to create secondary electron. Signal from this area is stable and not increase with increasing voltage. This area is called Ionization chamber region.

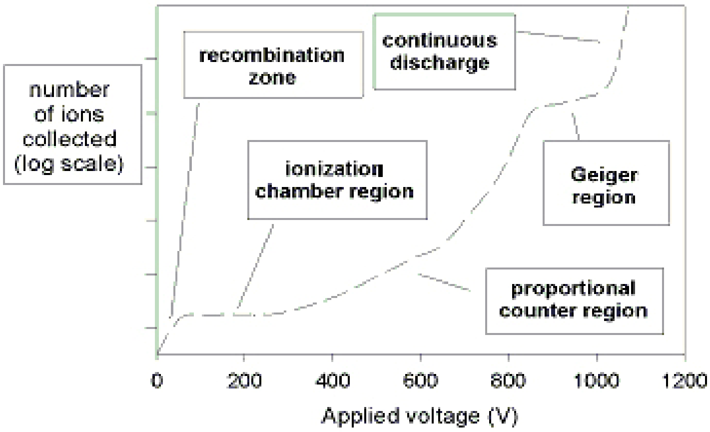

Figure 1.1 The differentregions of operation of gas-filled detector [21]

1.2.4 Air kerma-area product meter

Air Kerma-Area Product (KAP) meter is large-area transmission ionization chamber that cooperated with electronics part. In use, the transmission ionization chamber is placed in location to completely cover the area of x-ray field and perpendicular with the beam central axis. The design of currently KAP meter can measure both KAP and dose delivered by x-ray beam. It combines data from small ionization chamber that completely irradiated with conventional KAP chamber.

KAP meter is used to measure the radiation dose to air, time and area of the x-ray field of the patient skin. KAP is express in gray-cm^2 (Gycm^2), usually use in centigray-cm^2 (cGycm^2). KAP ionization chamber is placed beyond X-ray collimator. The chamber must cover the X-ray field for accurate reading. The reading can change from adjusting the exposure factor (kVp, mA or time) and field size of X-ray beam. If the area of chamber is larger than collimator opening at maximum field size, the charge corrected will increase or decrease in proportional to the area of field when change the field size. For example, an entrance skin dose 1 mGy with field size 5 x 5 cm^2 will produce 25 Gycm^2. If field size is 10 x 10 cm^2 with the same entrance skin dose 1 mGy, the KAP value is increase to 100 Gycm^2, which is 4 time of field size 5 x 5 cm^2. For ideal KAP meter, chamber has air equivalent wall that allows electronicequilibrium in the sensitive air volume and wall is thin enough to not attenuate incident photons. For real KAP meter, chamber composes of three plastic plates, typically 1-2 mm of PMMA per each and air sensitive layers is about 12-13 mm. The plates are covered with Indium oxide doped with tin (In_2O_3:Sn) or graphite. The graphite coated chamber has smaller energy dependence than Indium oxide coated chamber but, graphite coated chamber isn’t light transparent. It is disadvantage for graphite coated chamber in over couch X-ray system when light is used. In the other hand, this disadvantage is receivable when use in under couch X-ray system or light isn’t used.

KAP is easy to measure and use is indicator of risk better than entrance skin dose, because KAP is combined between entrance dose and field size. There are many problems in using KAP value. For example, if any material is placed between the chamber and patient, the patient will receive dose less than the display by KAP meter. The response of KAP meter can change over time, especially if meter are adjusted for couch transmission factor. The calibration should be done at least annually or any changes that might affect KAP value.

CHAPTER II
REVIEW LITERATURES

Vano E, et al [7] studied patient dose level for interventional radiology: a nation approach. Kerma area product, time of fluoroscopy and number of images were collected from 1,391 cases from 10 public hospitals. The third quartile of kerma area product was used as patient dose reference level. The maximum, minimum, mean, standard deviation and third quartile of kerma area product are shown in Table 2.1.

Table 2.1 Kerma area product ($Gycm^2$)

procedure	Number	Max	Min	Mean	SD	3^{rd} quartile
Fistulogram	180	83	0.6	9	13	12
Lower limb arteriography	685	608	2.4	58	53	73
Renal arteriography	55	397	7.7	75	85	89
Biliary drainage	205	428	0.6	61	81	80
Hepatic chemoembolization	151	830	27.4	216	17	289
Iliac stent	70	1136	14.1	91	148	94
Uterine embolization	45	677	26.6	170	154	236

From table 2.1, there are 2 procedures showing risk to radiation induced skin injury. They are Hepatic chemoembolization and Uterine embolization, which the third quartile are 289 $Gycm^2$ and 236 $Gycm^2$, respectively. The kerma area product value of 250 $Gycm^2$ with field size of 225 cm^2 represents dose of 1.1 Gy without backscatter or 1.4 Gy with backscatter.

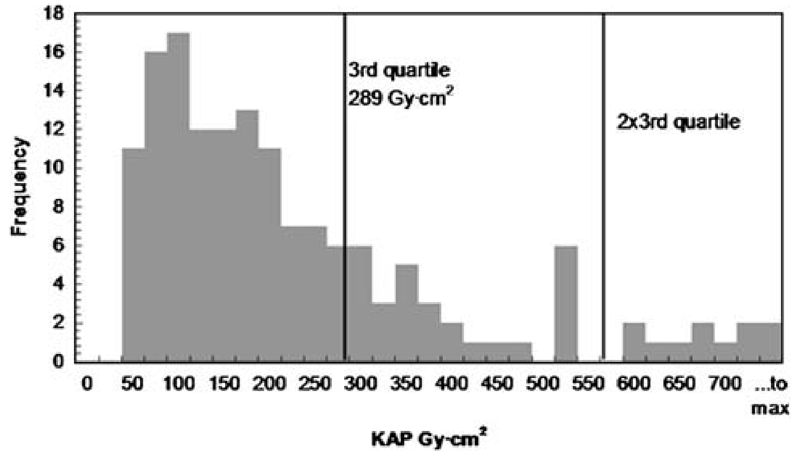

Figure 2.1 Patient dose value distribution of Hepatic chemoembolization.

From Figure 2.1, there were 11 cases receive radiation dose higher than twice of dose reference level. These cases would need an individual analysis and clinical follow-up for radiation induced skin injury.

Bor D, et al [8] studied the comparison of effective dose obtained from dose-area product and air kerma measurements in interventional radiology. The dose-area product (DAP, air kerma-area product) and entrance dose obtained in 162 patients who underwent interventional radiology. The thermoluminescent dosimeters (TLD) were attached on the patient skin, located by radiologist. The dose-area product and air kerma were measured by calibrated dose-area product meter. The dose-area product chamber was calibrated in situ with ion chamber. Air kerma were measured in specific distance then reading was corrected by inverse square law, backscatter factor and mass energy absorption coefficient. The dose-area products of each procedure were shown in table 2.2.

Table 2.2 Mean of dose-area product, time of Fluoroscopy and number of images.

Procedure		No.	DAP ($Gycm^2$)		Fluoroscopy time (min)	Number of images
			Fluoroscopy	Radiographic		
Hepatic	Diag	5	8	44	3.2	59
	Ther	14	19	57	7.7	59
Thoracic	Diag	3	9	39	8	72
Renal	Diag	6	22	64	5.2	62
	Ther	5	13	67.6	5	84
Lower extremity	Diag	29	2.8	11.5	1	44
	Ther	8	5.9	12	2.2	36
Upper extremity	Diag	9	4.1	7.9	5.7	59
	Ther	6	6	11.5	5.7	61
Cerebral	Diag	47	6	79.6	5.7	148
	Ther	5	16	85	9.4	171
Carotid	Diag	19	19	18	5	83
	Ther	2	7.9	14	8.6	101

In this study, the effective dose estimation was calculated from dose-area product and air kerma multiplied by conversion factor. The conversion factors were calculated by Monte Carlo techniques. The Entrance skin dose and Effective dose were shown in table 2.3.

From the result, the effective doses calculated from dose-area product are more accurate than effective doses calculated from air kerma because dose-area product has variation in field sizes. The DAP measurement for the effective dose calculation and thermoluminescent dosimeter for the skin dose estimates are found to be the most reliable methods for patient dosimetry.

Table 2.3 Entrance skin dose calculated from Air kerma, thermoluminescent dosimeter and effective doses calculated from dose-area product, Air kerma and thermoluminescent dosimeter.

		Entrance skin dose (mGy)		Effective dose (mSv)		
		From Air kerma	From TLD	From DAP	From Air kerma	From TLD
Hepatic	Diag	361	110	8.6	36	10.5
	Ther	542	74	10.5	50	6.9
Thoracic	Diag	260	29	6	31	3
Renal	Diag	622	772	13.7	33	3.8
	Ther	657	19.7	11.7	32	1
Lower extremity	Diag	68	28	3.5	11.7	2.9
	Ther	146	35.5	4.5	25	3.3
Upper extremity	Diag	73	18	0.562	0.65	0.6
	Ther	157	38	0.9	1.6	0.4
Cerebral	Diag	1120	344	3	14.6	3.5
	Ther	1310	457	3	14	3.5
Carotid	Diag	215	20.8	4.9	11	0.8
	Ther	154	72.9	2.5	4.7	0.9

Bor D, et al [10] measured dose-area product and patient skin dose in 325 cardiac catheterization patients. Data were collected from five different systems with the involvement of 11 cardiologists by used dose-area product meter, thermoluminescent dosimeter and Air kerma method. Patient dose and technique parameter were collected separately in 10 different projections. Mean of dose-area product for Coronary angiography (CA), Percutaneous transluminal coronary angioplasty (PTCA) and stent implantation (PT-SI), Coronary angiography and Percutaneous transluminal coronary angioplasty and stent implantation (CA-PT-SI), and ablation examination are 49.1 $Gycm^2$, 66.8 $Gycm^2$, 106.9 $Gycm^2$ and 124.7 $Gycm^2$, respectively. Mean of dose-area product and Entrance skin dose measured with radiochromic film for each system were shown in table 2.4

Table 2.4 Mean of total DAP ($\sum DAP_{meas}$(Gycm^2)), fluoroscopic DAP (DAP_{meas}(FL) (Gycm^2)), radiographic DAP (DAP_{meas}(DA) (Gycm^2)), fluoroscopy time (T_{FL}(mins)), number of radiographic frames (N_{DA}) and Entrance skin dose measured with radiochromic film (ESD_{rchf}(mGy)) for 5 fluoroscopic-radiographic systems.

Procedure		S1	S2	S3	S4	S5[a]	Mean
CA	$\sum DAP_{meas}$	32.7	35.5	74.5	53.5	-	49.1
	DAP_{meas}(FL)	16.3	11.4	21.2	20.9	-	17.9
	T_{FL}	4.54	2.95	4.09	4.8	-	4.3
	DAP_{meas}(DA)	16.4	24.2	53.3	32.6	-	31.3
	N_{DA}	720	793	730	771	-	794.6
	ESD_{rchf}	381.2	614.8	810	501.8	-	573.2
PT-SI	$\sum DAP_{meas}$	64.3	55.5	103.1	48.6	-	66.8
	DAP_{meas}(FL)	42	31	42.4	17.5	-	33.8
	T_{FL}	10.4	12.8	8.3	4.7	-	8.7
	DAP_{meas}(DA)	22.3	24.5	60.6	31.1	-	33
	N_{DA}	874	1141	837	659	-	843.8
	ESD_{rchf}	1316.5	1342.5	1394	1039.3	-	1278.75
CA-PT-SI	$\sum DAP_{meas}$	79.5	78.8	162.4	100.4	-	106.9
	DAP_{meas}(FL)	57.2	44.7	81.6	42.4	-	58.12
	T_{FL}	16.8	12	15.9	11.4	-	14.3
	DAP_{meas}(DA)	22.3	34.1	80.8	57.9	-	48.8
	N_{DA}	1154	1061	1077	1317	-	1138
	ESD_{rchf}	1707.1	1955.6	2483	1607.7	-	1989
ablation	$\sum DAP_{meas}$	-	-	-	-	124.7	124.7
	DAP_{meas}(FL)	-	-	-	-	124.3	124.3
	T_{FL}	-	-	-	-	31.21	31.21
	DAP_{meas}(DA)	-	-	-	-	0.4	0.4
	N_{DA}	-	-	-	-	27	27
	ESD_{rchf}	-	-	-	-	2724.6	2724.6

[a] This system was used only for ablation examination.

From the measurement of dose-area product and entrance skin dose measured with thermoluminescent dosimeter, the relationship between dose-area product and entrance skin doses calculated from air kerma was good correlation (R^2 = 0.91). But, poor correlation was found among dose-area product and Entrance skin doses calculated from thermoluminescent dosimeter (R^2 = 0.48). When use this relation, the skin doses can be calculated from dose-area product. The 2 Gy of skin dose of early transient erythema equals 130 $Gycm^2$ of dose-area product.

Cruces RR, et al [11] studied the estimation of effective dose in some digital angiographic and interventional procedures. Dose-area product was collected in 143 patients for 5 procedure of interventional radiology. Dose-area product meter was calibrated in situ and energy response of chamber was independent of energy within ±5% for tube potential between 50 and 100 kVp. Dose-area product was shown in table 2.5.

Table 2.5 Dose-area product and number of procedures.

Procedure	Number	DAP($Gycm^2$)			
		Range	Mean	Radiography	Fluoroscopy
Abdominal angiography	16	8-192	61	25	36
Arteriography of lower limbs	35	9-77	30	19	11
Dranage biliary	18	51-291	150	8	142
Embolization spermatic vein	20	7-260	75	2	73
Nephrostomy	54	1-213	56	4	52

In this study, Effective dose for each case was calculated by using program Eff-Dose version 1.02. Program Eff-Dose is based on 4 parameters is tube potential, total beam filtration, dose-area product and projection used. Dose-area product was shown in table 2.6.

Table 2.6 Effective dose (mSv)

Procedure	Effective dose (mSv)		Effective dose/Film	Effective dose/min
	Radiography	Fluoroscopy		
Abdominal angiography	3.1	5.1	0.1	0.8
Arteriography of lower limbs	3.8	2.4	0.1	0.6
Dranage biliary	1.8	36.4	0.5	1.1
Embolization spermatic vein	0.4	16.9	0.1	0.7
Nephrostomy	0.9	12.7	0.3	1.0

From table 2.6, the effective dose per radiography and per minute of fluoroscopy in each procedure can be used to estimate the effective dose of other patient in similar procedure.

McParland BJ [16] studied patient radiation dose in interventional radiological procedures. There are 177 diagnostic cases and 111 therapeutic cases. The fluoroscopy time, fluoroscopic and Radiographic dose-area product were recorded by computer in each procedure. Effective doses were calculated from dose-area product and dose-area product to effective dose conversion factor. This conversion factor was calculated from Monte Carlo simulations by using knowledge of beam quality, anatomical region and radiographic projection. Dose-area product to effective dose conversion factor was shown in table 2.7 and Fluoroscopy time, dose-area product and Effective dose were shown in table 2.8.

From result, Transjugular intrahepatic portosystemic shunt (TIPS) showed highest dose-area product and effective dose of 524 $Gycm^2$ and 83.9 mSv, respectively. This study presented the wide variation in patient radiation dose due to different of clinical technique and the types of X-ray equipment used.

Table 2.7 Dose-area product to effective dose conversion factor for each procedure.

Study	DAP to effective dose conversion factor ($mSvGy^{-1}cm^{-2}$)
Cerebral/ Carotid	0.10
Pulmonary/Chest	0.14
Hepatic/Abdomen	0.16
Renal/Pelvic	0.16
Femoral	0.16
Extremity	0.01

Table 2.8 Mean of Fluoroscopy time, dose-area product and Effective dose.

Procedure	Sample size	Fluoroscopy time (mins)	DAP ($Gycm^2$)		Effective dose (mSv)
			Fluoroscopy	Radiographic	
Diagnostic					
Cerebral	28	12.1	28.2	45.8	7.4
Carotid	11	10.3	22.9	26.4	4.9
Upper extremity	7	4.6	10.5	16.8	0.3
AV fistula	12	2.3	4.6	12.6	0.2
Thoracic	7	22.1	49.0	36.2	11.9
Nephrostography	13	4.0	12.4	2.2	2.4
Renal	6	5.1	17.7	22.1	6.4
PTC	16	14.6	76.9	3.3	12.8
CT aterial	17	10.0	69.0	11.6	12.9
Hepatic	7	12.1	74.9	61.0	21.7
Transjugular hepatic biopsy	8	6.8	30.8	3.4	5.5
Abdomen	21	8.0	46.1	72.1	18.9
Femoral	9	7.2	17.2	29.6	7.5
Lower extremity	15	7.5	28.0	51.9	0.8

Table 2.8 Mean of Fluoroscopy time, dose-area product and Effective dose. (Continued)

Procedure	Sample size	Fluoroscopy time (mins)	DAP ($Gycm^2$)		Effective dose (mSv)
			Fluoroscopy	Radiographic	
Therapeutic					
Cerebral	5	34.1	43.1	61.4	10.5
AV fistula	10	14.6	16.4	8.7	0.3
Thoracic	5	14.9	59.5	56.9	16.3
Biliary stent insertion/removal	30	7.1	40.5	2.6	6.9
TIPS	4	48.4	400	125	83.9
Nephrostomy	35	7.0	39.8	3.2	6.9
Renal	6	14.0	57.0	28.1	13.6
Other Abdomen Therapeutic Procedure	16	18.4	114	54.1	26.9

CHAPTER III
OBJECTIVE

This study was carried out to assess radiation dose to patients undergoing interventional radiology procedures at Ramathibodi Hospital. Patient dose of transarterial oily-chemoembolisation, femoral angiography, diagnostic cerebral angiography and therapeutic cerebral angiography were estimated. The aims of this study are.

1. To estimate the patient radiation dose from interventional radiology in Ramathibodi hospital.
2. To study the factors affecting the patient skin dose in the interventional radiology.

CHAPTER IV
MATERIALS AND METHODS

4.1 Materials

4.1.1 Radiographic-Fluoroscopic system

The evaluation of patient dose was carried out at the radiology department of Ramathibodi hospital. The interventional procedures were performed on two radiographic systems. The Transarterial oily-chemoembolization (TOCE) and Femoral angiography procedures were performed on Toshiba Infinix VC-i FPD with X-ray generator model XTP 8100G (single-plane x-ray system) whereas Diagnostic cerebral angiography and Therapeutic cerebral angiography (Brain AVM and DAVF embolization) were performed on Toshiba Infinix VB-i with X-ray generator model XTP 8100G (bi-plane x-ray system). The exposure parameters such as tube potential and tube current were controlled by automatic brightness control (ABC). The radiographic systems utilize 4 field diameters including 6 inches, 8 inches, 12 inches, and 16 inches for Infinix VC-I FPD and 5 inches, 7 inches, 9 inches and 12 inches for Infinix VB-I. Both radiographic systems are real-time image display, digital subtraction angiography (DSA) and roadmap with 1024 matrices. The frame rates can be adjusted between 1 to 20 frames per second for fluoroscopy dose reduction. The Half-Value-layer (HLV) tested at tube potential at 80 kVp and 74 kVp prior to the KAP calibration were 4.0 mmAl and 3.7 mmAl for Infinix VC-I FPD and Infinix VB-I, respectively.

Figure 4.1 Toshiba Infinix VC-i FPD radiographic-fluoroscopic system

Figure 4.2 Toshiba Infinix VB-i radiographic-fluoroscopic system

4.1.2 Ionization chamber

Accu-Pro™ was used for air-kerma area product meter calibration. Accu-Pro™ composes of control unit, ion chamber and kV sensor. The structure of ion chamber is 250 mm X 27 mm coaxial cylinder with 6 cm^3 active volume. The shortest pulse width is 10 ms and longest pulse width is 9999 second. The range of measuring dose is between 100 nGy to 700 Gy and measuring dose rate is between 10 nGy/s to 190 mGy/s. Dose rate dependence and energy dependence are within 5% for 0.4 mR/s - 80 R/s and 30 keV - 1.33 MeV, respectively. The energy dependence of ionization chamber is shown in figure 4.4. For kV sensor, the range of measuring tube potential is between 40 kV to 160 kV with 0.2 kV uncertainties. Operating temperature is 15°C to 35°C and the range of pressure is 60 to105 kPa. Control unit showed the type and calibration factors of each sensor, include the ion chamber temperature and the ambient pressure in self-testing when turn on.

Figure 4.3 Accu-Pro™ Radiation measurement system

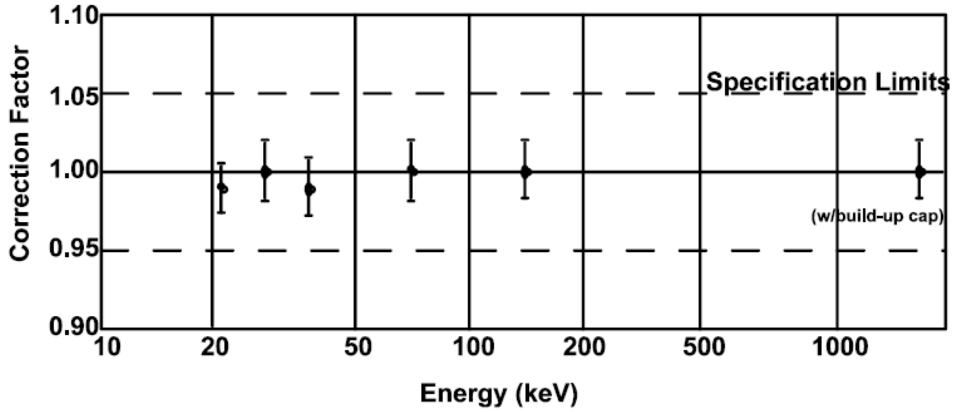

Figure 4.4 Energy dependence of ionization chamber

4.1.3 KAP meter

All X-ray tubes were equipped with built-in air-kerma area product meter (PTW Diamentor K1S) at the collimator exit with capability to display the cumulative air-kerma area product for Fluoroscopic and Radiographic examinations and displayed by PTW Diamentor ED. Air-kerma area product meter chamber is covers all radiation fields of radiographic-fluoroscopic system.

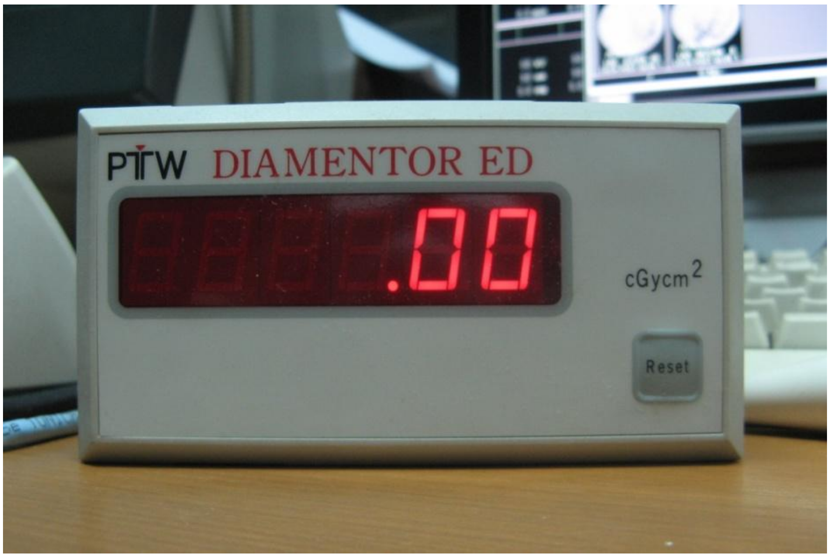

Figure 4.5 Air-kerma area product meter manufacturer PTW model Diamentor ED

4.2 Methods

The Radiographic-Fluoroscopic system performance was tested by Department of Medical Sciences before Air kerma-area product (KAP) calibration and data collection. KAP and Entrance dose (ED) were measured and calculated from KAP meter. This study was carried on two parts:

4.2.1 Air kerma-area product (KAP)

4.2.2 Entrance dose

4.2.1 Air kerma-area product (KAP)

The KAP meter calibration was performed separately in under and over couch installation. The calibration method is based on Technical Report Series no. 457.

4.2.1.1 KAP meter calibration

1) Check the KAP meter in the tube housing and a calibrated electrometer were connected.

2) For over couch installation set the calibrated diagnostic dosimeter follow step A and follow step B for under couch installation.

A. Place the detector of dosimeter on central axis of x-ray beam and 200 mm above the couch to avoid the backscatter radiation. For support the detector, the Styrofoam was used (Figure 4.6).

B. Place the detector of dosimeter on the tabletop and turn the sensitive side face to x-ray tube (Figure 4.7).

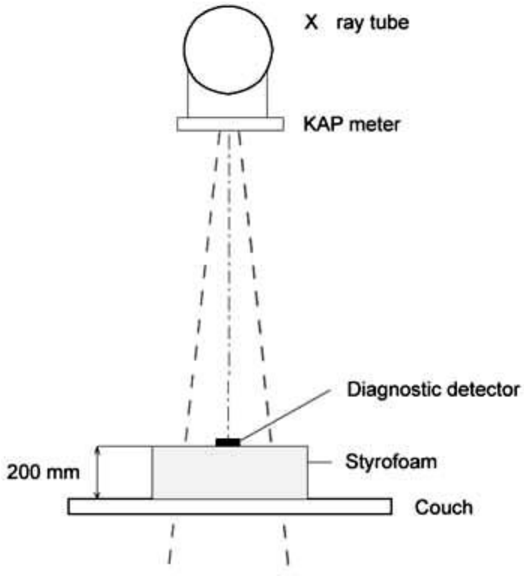

Figure 4.6 Over couch installation set up

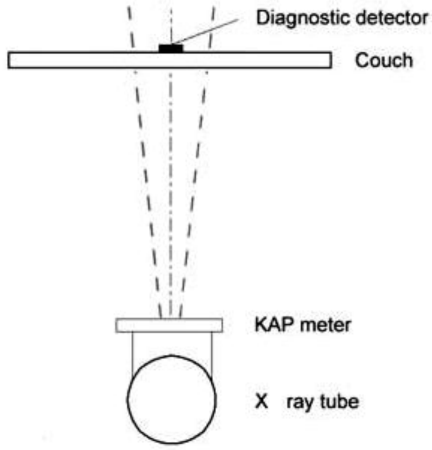

Figure 4.7 Under couch installation set up

3) Adjust the x-ray beam at the position of detector is approximately 100 x 100 mm^2.

4) Expose the detector and KAP meter with 50 kVp.

5) Record reading from the KAP meterand reference diagnostic dosimeter.

6) Repeat twice andrecordthe reading.

7) Repeat step 4. to 6. for 60, 70, 80, 90 and 100 kVp.

8) Replace the reference chamber by computer radiography cassette perpendicular to the central axis at the position of the reference chamber.

9) Expose the computer radiography cassette.

10) Produce a soft copy and determine the nominal beam area. The nominal beam area is area within 50% of maximum optical density or pixel value.

11) Calculate the calibration coefficient by using equation 4.1 and the reading must corrected for air density before calculation.

$$N_{P_{\mathrm{KA}},Q} = \frac{\bar{M}_Q^{\mathrm{ref}}}{\bar{M}_Q^{\mathrm{ref}}} N_{K,Q_0}^{\mathrm{ref}} k_Q^{\mathrm{ref}} A_{nom} \qquad (4.1)$$

Where $N_{P_{\mathrm{KA}},Q}$	is the calibration coefficient at beam quality Q.
$\bar{M}_Q^{\mathrm{KAP}}$	is mean reading from KAP meter.
$\bar{M}_Q^{\mathrm{ref}}$	is mean reading from reference diagnostic dosimeter.
N_{K,Q_0}^{ref}	is calibration coefficient of the reference dosimeter obtained at a beam quality Q_0.
k_Q^{ref}	is the factor correcting for the difference of the response between beam qualities $Q_0$and Q.
A_{nom}	is measured nominal beam area.

12) Plot graph between tube voltage and calibration coefficient of KAP meter.

4.2.1.2 KAP Calculation

The KAP was calculated for each projection from calibration coefficient and reading from KAP meter by using equation 4.2.

$$P_{\mathrm{KA}} = MN_{P_{\mathrm{KA}},Q} \quad (4.2)$$

Where P_{KA} is Air kerma-area product (KAP)

M is reading from KAP meter

$N_{P_{\mathrm{KA}},Q}$ is the calibration coefficient at beam quality Q.

4.2.2 Entrance dose

4.2.2.1 Half value layer (HVL) measurement

1) Set up the fluoroscopy in the manual mode.

2) Choose the parameter as 60 kVp, 100 mA and 20 ms.

3) Set the chamber of detector at the central of x-ray beam and collimate beam just covet the chamber.

4) Expose and record the reading 3 times.

5) Repeat step 4. by using aluminium thickness 2, 4, 6 mm to attenuate the x-ray beam.

6) Repeat step 4. And 5. for 70, 80, 90, 110 kVp.

7) Plot semi-log graph between the reading and aluminium thickness for finding HVL in each tube voltage.

8) Plot graph between tube voltage and HVL.

4.2.2.2 Entrance dose (ED) calculation

1) The Entrance dose was calculated for each projection from calibration coefficient and reading from KAP meter by using equation 4.3.

$$\mathrm{ED} = MN_{P_{\mathrm{KA}},Q}/A_{nom} \quad (4.3)$$

Where ED is Entrance dose.

M is reading from KAP meter.

$N_{P_{\mathrm{KA}},Q}$ is the calibration coefficient.

A_{nom} is measured nominal beam area.

2) Correct from calibrate distance to focal to skin distance (FSD) by inverse square law and multiply by backscatter factor for each projection.

4.2.3 Data collection

Evaluations were made on 120 patients who underwent Interventional Radiology exams such as transarterial oily-chemoembolization, femoralangiography, brain arterio-venous malformation embolization, dural arteriovenous fistula embolization. The transarterial oily-chemoembolization and femoral angiography procedures were performed on Toshiba Infinix VC-I FPD whereas diagnostic cerebral angiography and therapeutic cerebral angiography were performed on Toshiba Infinix VB-I. The patient data and technical parameter such as tube voltage, tube current, exposure time, frame rate, fluoroscopy time and number of image were recorded during each procedure, the couch positions were also recorded.

CHAPTER V
RESULTS AND DISCUSSIONS

5.1 KAP meter calibration

All build-in KAP meters were calibrated with ionization chamber. The calibration procedure was recommended by International Atomic Energy Agency (IAEA), which the calibrated energy covered all examination energy.

The calibration coefficients were plotted with tube voltage for 50 to 100 kV, the curves were shown in figure 5.1, 5.2 and 5.3 for tube of room 12A, 12B and tube of room 14 respectively.

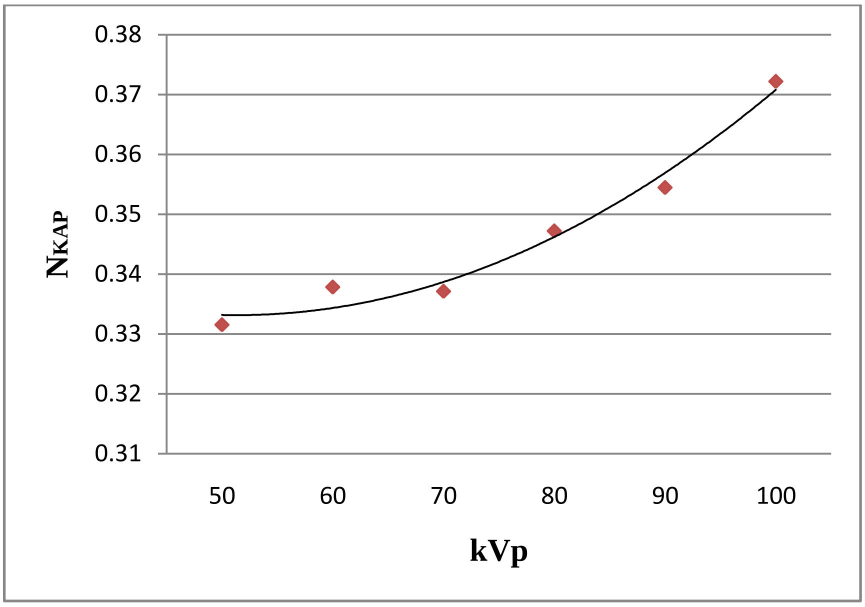

Figure 5.1 The calibration curve of Room 12A (Frontal) for 50 to 100 kVp

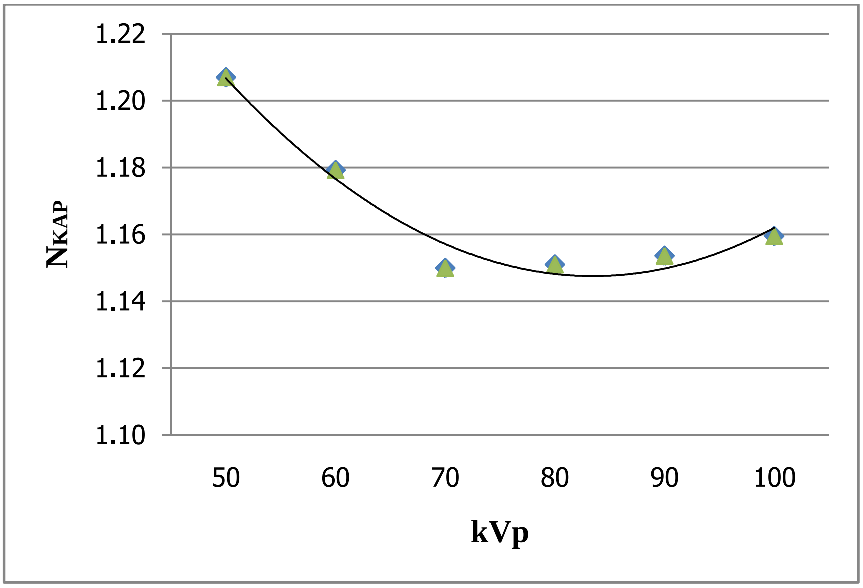

Figure 5.2 The calibration curve of Room 12B (Lateral) for 50 to 100 kVp

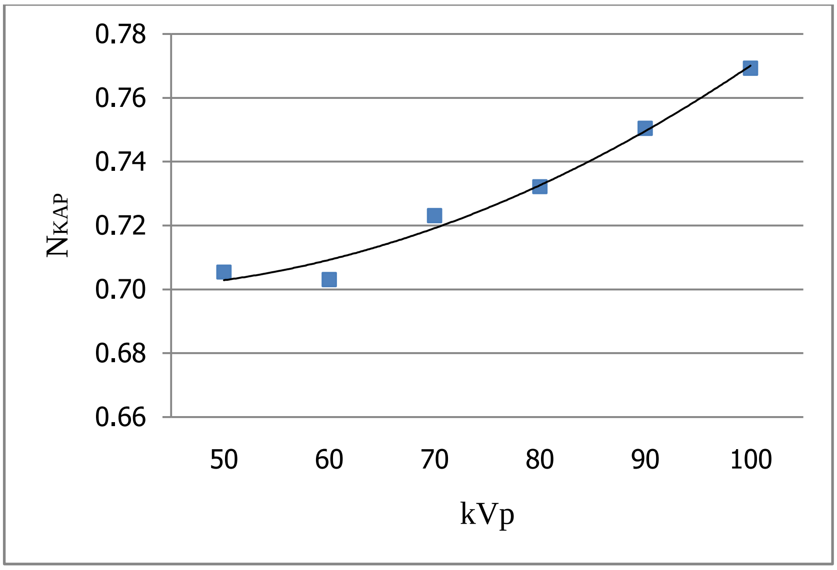

Figure 5.3 The calibration curve of Room 14 for 50 to 100 kVp

5.2 Patient information, Fluoroscopy and Radiography technique

The evaluation of patient radiation doses were performed in 120 patients, 78 patients were male and 42 patients were female. The evaluation was performed in 30 patients for each procedure. The mean age of male patients was 51.29±16.88 years and 53.43±20.94 years for female patients. The patient information, fluoroscopy and radiography technique are shown in table 5.1 for TOCE, 5.2 for femoral angiography, 5.3 for diagnostic cerebral angiography and 5.4 for therapeutic cerebral angiography.

The exposure parameters of fluoroscopy and radiography mode, such as tube potential and tube current, were controlled by automatic brightness control. From the result, The tube potential of fluoroscopy mode was fixed at 70 kVp in all procedures but tube potential of radiography mode was varied between 70-99 kVp for TOCE, 80-94 kVp for femoral angiography, 74-88 kVp and 74 kVp for frontal and lateral diagnostic cerebral angiography, 74-86 kVp and 68-84 kVp for frontal and lateral therapeutic cerebral angiography. The mean value of tube potential was 82.9 kVp, 80.3 kVp, 76 kVp (Frontal), 74 kVp (Lateral), 75.6 kVp (Frontal) and 74.6 kVp (Lateral), respectively. Fluoroscopy time and number of image were wide varied, fluoroscopy time varied between 3.7-50.9 mins, 1.6-20.4 mins, 4.3-33.3 mins and 9.5-126 mins and number of image varied between 39-248 pictures, 118-385 pictures, 63-926 pictures, 61-226 pictures, 114-1015 pictures and 102-891 pictures for TOCE, femoral angiography, diagnostic cerebral angiography and therapeutic cerebral angiography, respectively. The highest number of image was 1015 images and fluoroscopy time was 126 minutes in the lateral tube position of therapeutic cerebral angiography.

5.1 Patient radiation dose

In this study, the highest entrance dose was 362.63 cGy in the lateral tube position of therapeutic cerebral angiography. However, the highest KAP was from TOCE with value of 26,437.107 $cGycm^2$. The KAP and Entrance skin dose were shown in table 5.5 and 5.6. The mean value of KAP and Entrance skin dose were shown in table 5.7. There were two patients receiving entrance dose higher than 3 Gy in a frontal view of therapeutic cerebral angiography. This dose level is higher than a threshold dose for temporary epilation. Complicated procedure requires more operating time and it cause more radiation dose to patients than common and non-complicated procedure.

In this study, we found that larger irradiated field such as TOCE gave higher KAP than smaller field procedure of therapeutic cerebral angiography. However, the ED from TOCE was smaller due to it required less irradiation time.

Table 5.7 shows the comparison between KAP and entrance skin dose from this study with other published data. The mean KAP of this study was lower than other study in TOCE and femoral angiography except compare with E Vano [14] in TOCE. In Diagnostic and therapeutic cerebral angiography procedure, the mean KAP was lower than other study when compared with each tube, but higher than some study when compared with both tube.

To utilize the displayed air kerma area product values from the console screen, equation of graph between air KAP and entrance skin dose converting air kerma area product to entrance skin dose was used. Curves and equations of graph were shown in figure 5.4 to 5.9. In this study, to set up a concerned level for deterministic risk of 2 Gy, the correlation (R^2) between the KAP values and the calculated entrance skin dose of 0.825, 0.982, 0.863, 0.769, 0.915, 0.699 for TOCE, femoral angiography, diagnostic cerebral angiography frontal and lateral, therapeutic cerebral angiography frontal and lateral, respectively, were found. The correlations present the agreement between air kerma area product and entrance skin dose in each procedure. The corresponding air kerma area product values were 410.77, 606.66, 162.73, 464.11, 118.12 and 335.21 $Gycm^2$ respectively.

Table 5.1 The patient's information and technique parameter in TOCE procedure.

	Patient number				
	1	2	3	4	5
Gender	M	M	F	F	M
Age (years)	71	64	68	75	51
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	4.5	38.1	6.6	7.9	13.2
Radiography mode					
kV	80-82	80-99	80-94	80-83	82-88
mA	125	100-125	70-400	125	125
ms	73.6-82.3	57.9-81	67.6-82.8	68.9-81.7	77-75.6
No. of series	3	9	3	6	5
No. of images	57	248	67	138	110
FOV (inch)	12,16	8,12,16	12,16	12,16	12,16
SID (cm)	91	91-92	93	90	99

Table 5.1 The patient's information and technique parameter in TOCE procedure. (Continued)

	Patient number				
	6	7	8	9	10
Gender	M	M	M	M	M
Age (years)	47	64		69	47
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	18.2	17.3	7.4	13.3	4.5
Radiography mode					
kV	70-83	70-87	80	80-86	86
mA	63-125	66-125	125	125	125
ms	7.1-89.7	7.3-89.3	52.9-66.1	53.5-85.5	84.4-85.3
No. of series	5	5	5	6	2
No. of images	170	125	109	89	73
FOV (inch)	12,16	12,16	12,16	8,12,16	16
SID (cm)	92	90-94	94	93	95

Table 5.1 The patient's information and technique parameter in TOCE procedure. (Continued)

	Patient number				
	11	12	13	14	15
Gender	M	M	M	M	M
Age (years)	41	43	65	56	46
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	4.7	3.7	9.8	3.9	5.2
Radiography mode					
kV	82-85	80-84	80	90-94	86-90
mA	125	125	125	125	125
ms	78.3-81.8	80.3-86.6	57.3-70	72-78.2	72.1-76.9
No. of series	3	3	3	4	4
No. of images	80	39	71	106	120
FOV (inch)	12,16	12,16	12,16	12,16	8,12,16
SID (cm)	90	99	91-93	94	92

Table 5.1 The patient's information and technique parameter in TOCE procedure. (Continued)

	Patient number				
	16	17	18	19	20
Gender	M	M	M	M	M
Age (years)	73	63	51	30	62
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	6	21	5.3	8.8	16.2
Radiography mode					
kV	80-82	80-82	85-88	89-93	81-84
mA	125	125	125	125	125
ms	77.7-94.2	49.8-62.1	73.4-84.4	74.8-79.2	51.5-56.8
No. of series	3	8	3	4	4
No. of images	86	123	56	72	97
FOV (inch)	12,16	12,16	16	12,16	12,16
SID (cm)	90	90	101	100-108	90-91

Table 5.1 The patient's information and technique parameter in TOCE procedure. (Continued)

	Patient number				
	21	22	23	24	25
Gender	M	M	M	M	F
Age (years)	34	40	49	55	66
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	7.2	15.7	7.4	28.4	31.3
Radiography mode					
kV	70-87	80	86-88	80	70-82
mA	84-125	125	125	125	82-125
ms	8.6-83.6	52.6-66.3	71.4-82.5	42.7-54.1	8.5-86
No. of series	5	6	4	3	8
No. of images	133	128	98	53	171
FOV (inch)	8,12,16	12,16	12,16	12,16	8,12,16
SID (cm)	90	90	92	93	91-102

Table 5.1 The patient's information and technique parameter in TOCE procedure. (Continued)

	Patient number				
	26	27	28	29	30
Gender	M	M	M	M	M
Age (years)	71	63	50	68	61
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	31.6	44.7	50.9	8.8	6.6
Radiography mode					
kV	70-95	83-86	80-84	80-83	86-88
mA	125-130	125	125	125	125
ms	11.6-80.9	67.7-90.9	45.3-82.4	73.4-79.5	72-82.5
No. of series	4	12	8	3	3
No. of images	96	147	168	60	55
FOV (inch)	8,12,16	12,16	6,12,16	12,16	16
SID (cm)	91-101	90-98	90-98	90	91

Table 5.2 The patient's information and technique parameter in femoral angiography procedure.

	Patient number				
	1	2	3	4	5
Gender	F	M	M	F	M
Age (years)	53	73	71	80	69
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	2.8	5.6	5.1	6.5	7.1
Radiography mode					
kV	80	80	80-89	80	80-94
mA	20-125	32-125	32-125	32-125	32-125
ms	6.9-70.7	7.8-74.5	7.4-86.9	6.9-70.7	7.8-87.3
No. of series	6	9	6	5	6
No. of images	216	227	170	134	198
FOV (inch)	12,16	16	16	16	12,16
SID (cm)	91-115	100-116	102-116	101-111	98-115

Table 5.2 The patient's information and technique parameter in femoral angiography procedure. (Continued)

	Patient number				
	6	7	8	9	10
Gender	F	F	F	M	F
Age (years)	60	65	68	59	38
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	2.7	2	3.6	15.4	3
Radiography mode					
kV	80	80	80	80-94	80
mA	32-125	32-125	32-125	20-125	20-125
ms	8.5-53.5	7.9-23.4	7.3-31.4	8-69.2	7.6-34.6
No. of series	6	5	6	6	5
No. of images	179	183	224	186	118
FOV (inch)	16	16	16	16	16
SID (cm)	100-109	90-120	95-107	90-106	91-92

Table 5.2 The patient's information and technique parameter in femoral angiography procedure. (Continued)

	Patient number				
	11	12	13	14	15
Gender	F	M	F	M	M
Age (years)	85	70	72	41	73
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	4.7	4	7.3	7.3	4.2
Radiography mode					
kV	80	80	80	80	80-82
mA	20-125	32-125	32-125	20-125	32-125
ms	6.1-45.7	9.2-54.8	8.6-67.6	8.4-73.4	7.4-88.4
No. of series	8	5	7	6	6
No. of images	270	137	163	265	199
FOV (inch)	16	16	16	16	16
SID (cm)	100-109	100-111	93-119	100-108	102-109

Table 5.2 The patient's information and technique parameter in femoral angiography procedure. (Continued)

	Patient number				
	16	17	18	19	20
Gender	M	M	F	F	F
Age (years)	59	72	75	85	78
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	5.2	3.6	6.2	4	6
Radiography mode					
kV	80	80	80	80	80
mA	32-125	32-125	20-160	20-125	20-125
ms	8.4-70.4	8-86.6	7.7-51.4	7.8-32	6.8-42.7
No. of series	8	6	7	6	6
No. of images	310	191	175	241	176
FOV (inch)	16	16	16	16	16
SID (cm)	94-107	102-113	93-111	97-109	91-105

Table 5.2 The patient's information and technique parameter in femoral angiography procedure. (Continued)

	Patient number				
	21	22	23	24	25
Gender	F	M	M	F	M
Age (years)	22	53	71	62	73
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	4.7	4.1	4.8	5.9	20.4
Radiography mode					
kV	80	80-92	80	80	80
mA	32-125	32-125	50-125	20-125	32-125
ms	7.4-29.4	7.4-85.5	7.9-76.8	8.1-68.6	8.2-71.3
No. of series	8	6	7	6	6
No. of images	320	166	331	180	197
FOV (inch)	12,16	16	16	16	16
SID (cm)	102-110	92-102	91-120	90-103	97-113

Table 5.2 The patient's information and technique parameter in femoral angiography procedure. (Continued)

	Patient number				
	26	27	28	29	30
Gender	M	F	F	M	M
Age (years)	39	62	76	55	51
Fluoroscopy mode					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	5.6	15.2	1.6	3.3	6.2
Radiography mode					
kV	80	80	80	80	80
mA	20-125	20-125	20-125	20-125	32-125
ms	8.3-29.7	8.1-63.4	7.7-56.9	7.7-39.9	7.9-64.5
No. of series	7	9	5	6	11
No. of images	369	337	181	194	385
FOV (inch)	16	16	16	16	16
SID (cm)	92-112	100-110	102-113	96-104	92-103

Table 5.3 The patient’s information and technique parameter in diagnostic cerebral angiography procedure.

	Patient number				
	1	2	3	4	5
Gender	M	M	M	M	M
Age (years)	59	18	77	65	57
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	21	8.7	8.4	25.5	11.9
Radiography mode					
Frontal					
kV	74-88	74	74-79	74-79	74-84
mA	160-630	160	160-630	160-630	160-630
ms	19-81	53-64	18-79	18-83	18-76
No. of series	9	4	5	8	7
No. of images	794	114	510	586	921
FOV (inch)	9	9	9	9	9
SID (cm)	94-110	94-97	93-110	93-110	93-110
Lateral					
kV	74	74	74	74	74
mA	400	400	400	400	400
ms	50-60	32-40	48-61	33-57	30-45
No. of series	6	4	3	6	3
No. of images	170	114	94	170	89
FOV (inch)	9,12	9	9,12	9,12	9
SID (cm)	110-120	107-110	109-120	106-113	106-109

Table 5.3 The patient's information and technique parameter in diagnostic cerebral angiography procedure. (Continued)

	Patient number				
	6	7	8	9	10
Gender	M	M	M	M	F
Age (years)	42	27	60	22	25
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	21.6	33.3	14.9	6.2	5.8
Radiography mode					
Frontal					
kV	74-79	74-79	74	74-79	74
mA	160-400	160-400	160-630	160	160
ms	41-78	50-82	18-63	70-83	67-74
No. of series	5	11	6	4	2
No. of images	152	226	718	124	63
FOV (inch)	7,9	5,9	9	9	9
SID (cm)	94-96	93-101	93-110	94-98	93
Lateral					
kV	74	74	74	74	74
mA	400	400	400	400	400
ms	16-36	39-60	42-58	27-47	41-45
No. of series	5	11	3	4	2
No. of images	152	226	94	124	63
FOV (inch)	9,12	7,12	9,12	12	9
SID (cm)	109-118	106-119	109-120	111-116	108-110

Table 5.3 The patient's information and technique parameter in diagnostic cerebral angiography procedure. (Continued)

	Patient number				
	11	12	13	14	15
Gender	F	F	M	M	M
Age (years)	49	45	69	14	15
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	12.6	7.7	8.9	9.7	10.7
Radiography mode					
Frontal					
kV	74-87	74-87	74-87	74	74
mA	160-630	160-630	160-320	160	160
ms	17-72	18-66	20-64	34-48	56-69
No. of series	6	6	5	4	4
No. of images	712	708	319	117	110
FOV (inch)	9	9	9,12	9	9
SID (cm)	93-110	94-110	93-110	93-94	93-94
Lateral					
kV	74	74	74	74	74
mA	400	400	400	400	400
ms	40-54	40-44	29-51	26-35	27-32
No. of series	3	3	4	4	4
No. of images	88	84	111	117	110
FOV (inch)	9	9	12	9,12	9
SID (cm)	110-112	108-109	111-119	107-120	107-108

Table 5.3 The patient's information and technique parameter in diagnostic cerebral angiography procedure. (Continued)

	Patient number				
	16	17	18	19	20
Gender	M	F	M	F	F
Age (years)	59	21	49	41	78
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	14.3	5.2	9.5	5.8	19.3
Radiography mode					
Frontal					
kV	74-87	74	74	74-87	74-86
mA	160-630	160	160	160-320	160-320
ms	18-68	79-82	67-73	20-76	19-82
No. of series	6	3	5	4	5
No. of images	712	99	144	300	510
FOV (inch)	9	9	9	9	9
SID (cm)	97-110	93-95	93-97	93-110	93-110
Lateral					
kV	74	74	74	74	74
mA	400	400	400	400	400
ms	34-39	30-38	36-58	44-59	31-39
No. of series	3	3	5	3	3
No. of images	88	99	144	92	94
FOV (inch)	9	9	9,12	9,12	9
SID (cm)	108-109	107-109	106-119	109-120	106-110

Table 5.3 The patient's information and technique parameter in diagnostic cerebral angiography procedure. (Continued)

	Patient number				
	21	22	23	24	25
Gender	M	F	F	M	F
Age (years)	36	32	62	67	28
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	12.7	4.3	14.5	13.1	13.1
Radiography mode					
Frontal					
kV	74-79	74	74	74-79	74-79
mA	125-400	160-630	160	160	160
ms	43-100	18-58	51-60	75-80	67-77
No. of series	6	3	5	4	4
No. of images	203	269	141	103	120
FOV (inch)	9,12	9	9	9,12	9
SID (cm)	93-105	93-110	93-94	95-105	94-98
Lateral					
kV	74	74	74	74	74
mA	400	400	400	400	400
ms	28-55	31-33	32-40	49-57	26-32
No. of series	4	2	5	4	4
No. of images	117	61	141	103	120
FOV (inch)	9	9	9	12	9
SID (cm)	103-108	108-111	107-111	118-120	105-111

Table 5.3 The patient's information and technique parameter in diagnostic cerebral angiography procedure. (Continued)

	Patient number				
	26	27	28	29	30
Gender	F	M	F	F	F
Age (years)	35	62	50	54	73
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	26.7	16.3	7.5	22.8	6.1
Radiography mode					
Frontal					
kV	74-84	74-84	74-79	74-81	74-87
mA	125-630	160-400	160	160-630	160-400
ms	17-98	17-77	71-81	20-80	15-51
No. of series	11	7	3	6	7
No. of images	812	383	96	355	926
FOV (inch)	5,9	9,12	9	9,12	9
SID (cm)	93-122	93-110	93	93-123	93-110
Lateral					
kV	74	74	74	74	74
mA	400	320-400	400	400	400
ms	33-42	15-79	50-59	41-58	31-32
No. of series	6	6	3	5	3
No. of images	167	175	96	147	94
FOV (inch)	9	9,12	9	9,12	9
SID (cm)	107-111	108-120	110-113	111-121	109

Table 5.4 The patient's information and technique parameter in therapeutic cerebral angiography procedure.

	Patient number				
	1	2	3	4	5
Gender	M	M	F	M	F
Age (years)	66	13	62	52	42
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	70.6	10.9	84.9	96.8	9.9
Radiography mode					
Frontal					
kV	74-79	74-79	74-79	74-79	74
mA	125-400	125-160	160-400	160-400	160
ms	40-90	48-100	40-100	70-83	68-83
No. of series	17	7	18	13	5
No. of images	431	138	419	298	147
FOV (inch)	5,7,9	5,9	7,9	5,7,9	9
SID (cm)	93-102	94-100	93-101	93-97	94-110
Lateral					
kV	74-84	74	74	74	74-82
mA	160-400	400	400	200-400	160-400
ms	32-100	33-44	31-48	28-84	27-100
No. of series	18	6	17	14	6
No. of images	427	102	387	310	165
FOV (inch)	5,7,9,12	5,9	7,9,12	5,7,9,12	9,12
SID (cm)	111-118	107-113	106-120	104-120	108-119

Table 5.4 The patient's information and technique parameter in therapeutic cerebral angiography procedure. (Continued)

	Patient number				
	6	7	8	9	10
Gender	F	M	M	M	M
Age (years)	12	49	40	38	52
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	59.3	17.8	50.1	22.8	19.3
Radiography mode					
Frontal					
kV	74-79	74-79	74-79	74-79	79
mA	125-160	160	125-160	160	160
ms	49-93	72-78	49-99	62-75	74-82
No. of series	15	8	20	11	5
No. of images	337	165	528	210	131
FOV (inch)	7,9	5,9	5,7,9	5,9	5,9
SID (cm)	93-103	93-94	93-98	93-97	94-96
Lateral					
kV	74-82	74-84	70-74	74	74
mA	160-400	125-400	34-400	400	400
ms	29-100	54-100	4.9-58	48-57	27-38
No. of series	17	12	18	11	5
No. of images	483	232	891	210	131
FOV (inch)	7,9,12	7,12	5,9,12	5,9	12
SID (cm)	115-120	119-120	112-120	108-111	109-116

Table 5.4 The patient's information and technique parameter in therapeutic cerebral angiography procedure. (Continued)

	Patient number				
	11	12	13	14	15
Gender	M	M	M	F	M
Age (years)	53	15	35	34	26
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	40.6	9.6	9.5	35	25.6
Radiography mode					
Frontal					
kV	74	74-79	79	74-79	74-79
mA	160	160	160	160-400	160-400
ms	54-73	65-73	71-76	42-82	41-83
No. of series	14	5	4	14	13
No. of images	359	130	114	270	293
FOV (inch)	7,9,12	9	9	5,7,9	5,9
SID (cm)	93-95	93-95	93	93-97	93-94
Lateral					
kV	74-84	74	74	74-79	74-84
mA	160-400	400	400	160-400	160-400
ms	37-100	34-60	41-65	28-90	36-100
No. of series	14	5	4	16	15
No. of images	359	130	114	362	407
FOV (inch)	7,9,12	9,12	9,12	5,7,9,12	5,9
SID (cm)	106-120	106-120	108-120	105-120	107-119

Table 5.4 The patient’s information and technique parameter in therapeutic cerebral angiography procedure. (Continued)

	Patient number				
	16	17	18	19	20
Gender	M	M	F	F	F
Age (years)	39	62	65	10	68
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	22.3	126	60.3	51.8	57.3
Radiography mode					
Frontal					
kV	74-84	74-83	74-86	74	74
mA	160-630	125-400	125-400	160	160
ms	20-79	39-83	19-93	40-62	57-74
No. of series	12	24	18	6	15
No. of images	449	568	602	166	344
FOV (inch)	9,12	7,9,12	5,7,9	5,9	5,9
SID (cm)	93-110	93-102	93-110	93-94	97-101
Lateral					
kV	74-84	74	74-83	74	74
mA	160-400	400	160-400	400	320-400
ms	47-100	28-82	27-97	23-38	18-31
No. of series	13	23	19	6	15
No. of images	325	562	526	166	344
FOV (inch)	7,9,12	7,9,12	5,7,9,12	5,9	5,9
SID (cm)	107-112	105-120	105-120	107-114	108-120

Table 5.4 The patient's information and technique parameter in therapeutic cerebral angiography procedure. (Continued)

	Patient number				
	21	22	23	24	25
Gender	M	F	M	M	M
Age (years)	59	48	40	21	58
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	60.2	17.8	25.1	36.8	29.9
Radiography mode					
Frontal					
kV	74-79	74-84	74	74-79	74-82
mA	160-400	160-320	160	160	400-544
ms	57-74	20-100	64-70	71-81	5.5-59
No. of series	21	20	7	11	14
No. of images	439	581	161	215	263
FOV (inch)	5,9	5,9	5,9	9,12	5,7,9
SID (cm)	93-104	93-110	93-94	93-98	99-100
Lateral					
kV	74	74-84	70-74	70-74	70-74
mA	400	160-400	16-400	16-400	400-610
ms	18-31	32-100	2.9-45	33-51	5.5-73
No. of series	21	19	8	11	14
No. of images	439	436	182	215	263
FOV (inch)	5,9,12	5,9,12	9,7,12	9,12	7,9,12
SID (cm)	108-120	106-114	107-119	113-120	110-119

Table 5.4 The patient's information and technique parameter in therapeutic cerebral angiography procedure. (Continued)

	Patient number				
	26	27	28	29	30
Gender	F	F	F	M	M
Age (years)	14	56	50	16	48
Fluoroscopy mode					
Frontal					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Lateral					
kV	70	70	70	70	70
Pulse per sec	15	15	15	15	15
Fluoroscopy time (min)	26.3	14.1	43.8	38	30.6
Radiography mode					
Frontal					
kV	74-84	74-81	74-79	74-81	74
mA	125-320	125-160	160-630	160-630	400
ms	18-99	59-82	5.5-78	16-69	41-66
No. of series	12	10	20	24	6
No. of images	476	286	1015	930	157
FOV (inch)	5,7,9	7,9	5,9,12	5,9,12	9,12
SID (cm)	94-110	93-100	93-110	93-110	93-105
Lateral					
kV	74	74-82	68-84	74-84	74-84
mA	400	160-400	160-610	160-400	125-400
ms	27-60	21-99	5.5-100	21-100	46-100
No. of series	12	11	20	24	7
No. of images	225	308	581	566	194
FOV (inch)	5,7,9,12	7,9,12	5,9,12	5,9,12	9,12
SID (cm)	108-120	106-119	110-119	107-120	116-119

Table 5.5 Air kerma area product.

Air kerma area product **(cGycm^2)**	Patient number				
	1	2	3	4	5
TOCE	4384.99	22796.12	11051.35	9151.31	10248.87
Femoral angiography	2190.52	2354.06	5715.56	3350.59	6526.89
Diagnostic cerebral angiography					
Frontal	7738.34	1020.09	3856.16	5987.20	9136.35
Lateral	6732.72	2521.19	3642.37	6212.68	2372.69
Therapeutic cerebral angiography					
Frontal	6483.87	988.72	13892.61	4796.47	1344.34
Lateral	15666.14	2064.59	12036.90	14523.26	3738.06

Table 5.5 Air kerma area product. (Continued)

Air kerma area product **(cGycm^2)**	Patient number				
	6	7	8	9	10
TOCE	9201.68	8834.77	5967.96	6810.70	4518.72
Femoral angiography	1749.81	884.34	2528.29	6655.52	1129.72
Diagnostic cerebral angiography					
Frontal	1428.18	4316.59	6128.64	994.51	714.28
Lateral	3406.59	9682.01	3033.10	3700.83	1385.11
Therapeutic cerebral angiography					
Frontal	5019.29	2531.71	3681.67	3551.96	1748.68
Lateral	11946.69	8801.78	8469.40	5807.31	3314.73

Table 5.5 Air kerma area product. (Continued)

Air kerma area product **(cGycm^2)**	Patient number				
	11	12	13	14	15
TOCE	6357.67	3401.71	4291.48	9360.47	8709.55
Femoral angiography	2150.22	1825.28	2162.86	2664.55	2701.70
Diagnostic cerebral angiography					
Frontal	4213.51	4517.88	2257.92	685.39	952.55
Lateral	1969.86	1918.06	3619.37	2752.25	1516.35
Therapeutic cerebral angiography					
Frontal	2551.40	1296.79	1485.71	2540.99	3795.91
Lateral	11632.09	3467.89	4873.89	11902.41	10620.10

Table 5.5 Air kerma area product. (Continued)

Air kerma area product **(cGycm^2)**	Patient number				
	16	17	18	19	20
TOCE	6586.18	8539.56	5480.59	7514.90	6700.25
Femoral angiography	6461.16	2919.03	2357.79	2062.47	2130.24
Diagnostic cerebral angiography					
Frontal	4931.85	721.52	1170.54	1911.31	3677.40
Lateral	1888.46	1899.60	4816.15	3395.10	1974.21
Therapeutic cerebral angiography					
Frontal	5979.92	23000.18	6820.57	2532.62	3288.01
Lateral	12128.70	19270.59	13876.46	6161.65	6935.83

Table 5.5 Air kerma area product. (Continued)

Air kerma area product **(cGycm^2)**	Patient number				
	21	22	23	24	25
TOCE	6318.40	7923.71	9007.31	5723.63	12807.13
Femoral angiography	1415.42	1188.03	4678.55	3121.86	7214.33
Diagnostic cerebral angiography					
Frontal	6045.14	2815.85	1352.13	1361.70	812.15
Lateral	3881.92	1146.57	3262.57	5741.55	2485.18
Therapeutic cerebral angiography					
Frontal	7796.15	3906.31	1733.05	2675.00	6247.25
Lateral	15846.51	10024.63	6759.47	9074.32	8291.31

Table 5.5 Air kerma area product. (Continued)

Air kerma area product **(cGycm^2)**	Patient number				
	26	27	28	29	30
TOCE	17465.36	26437.11	15648.49	5552.04	6190.34
Femoral angiography	2082.47	4477.96	2181.47	2048.89	4126.50
Diagnostic cerebral angiography					
Frontal	6896.99	2632.24	1262.56	5064.08	4725.94
Lateral	4047.79	4400.26	3425.26	6393.43	1797.26
Therapeutic cerebral angiography					
Frontal	5164.93	3574.21	11185.18	7097.54	3731.38
Lateral	7016.59	9734.28	17679.40	12985.41	7293.79

Table 5.6 Entrance skin dose.

Entrance skin dose	Patient number				
(mGy)	1	2	3	4	5
TOCE	167.44	1212.18	436.89	382.68	428.67
Femoral angiography	81.53	77.11	198.35	114.16	225.73
Diagnostic cerebral angiography					
Frontal	926.92	121.48	446.52	694.10	1100.10
Lateral	246.16	138.99	133.17	278.36	129.14
Therapeutic cerebral angiography					
Frontal	1293.48	236.34	3008.47	1011.39	155.49
Lateral	979.47	187.88	665.10	846.98	151.25

Table 5.6 Entrance skin dose. (Continued)

Entrance skin dose	Patient number				
(mGy)	6	7	8	9	10
TOCE	347.66	367.99	206.96	331.44	159.65
Femoral angiography	52.60	25.73	79.30	194.18	36.97
Diagnostic cerebral angiography					
Frontal	235.07	1015.20	774.77	118.68	85.07
Lateral	109.00	563.13	107.78	110.48	75.97
Therapeutic cerebral angiography					
Frontal	885.47	644.71	771.04	900.88	353.32
Lateral	692.21	526.20	433.19	493.13	97.70

Table 5.6 Entrance skin dose. (Continued)

Entrance skin dose	Patient number				
(mGy)	11	12	13	14	15
TOCE	246.68	102.37	163.83	354.91	426.11
Femoral angiography	69.64	59.78	72.56	87.45	91.21
Diagnostic cerebral angiography					
Frontal	465.69	495.78	187.17	77.03	107.05
Lateral	108.59	105.74	108.05	94.88	82.53
Therapeutic cerebral angiography					
Frontal	376.29	154.73	178.33	377.73	774.75
Lateral	596.12	150.85	165.06	831.13	938.35

Table 5.6 Entrance skin dose. (Continued)

Entrance skin dose	Patient number				
(mGy)	16	17	18	19	20
TOCE	246.73	356.28	193.67	236.32	244.88
Femoral angiography	216.12	95.52	73.07	67.64	71.29
Diagnostic cerebral angiography					
Frontal	556.50	83.45	135.39	223.43	429.23
Lateral	103.57	103.39	173.72	122.79	108.83
Therapeutic cerebral angiography					
Frontal	542.24	3626.28	1135.80	665.91	636.76
Lateral	617.01	716.87	874.45	626.29	559.14

Table 5.6 Entrance skin dose. (Continued)

***Entrance skin dose* (mGy)**	Patient number				
	21	22	23	24	25
TOCE	360.38	293.91	362.50	250.11	558.46
Femoral angiography	42.46	35.99	133.28	92.63	246.78
Diagnostic cerebral angiography					
Frontal	518.51	335.34	161.03	122.07	96.72
Lateral	214.00	63.21	179.86	171.40	137.00
Therapeutic cerebral angiography					
Frontal	1444.13	783.83	311.44	300.01	1347.70
Lateral	901.99	932.28	327.51	481.72	631.61

Table 5.6 Entrance skin dose. (Continued)

***Entrance skin dose* (mGy)**	Patient number				
	26	27	28	29	30
TOCE	666.15	1037.77	1272.58	211.57	219.08
Femoral angiography	60.20	143.78	74.11	66.92	124.76
Diagnostic cerebral angiography					
Frontal	1082.65	281.95	150.70	449.80	534.66
Lateral	226.48	151.47	187.86	208.47	99.08
Therapeutic cerebral angiography					
Frontal	995.23	485.10	1472.95	1029.47	396.18
Lateral	318.64	468.28	1498.66	736.27	312.50

Table 5.7 Mean Fluoroscopy, KAP and ESD of this study and other study.

Procedure		**Study**	**Mean Fluoroscopy time (min)**	**Mean KAP ($Gycm^2$)**	**Mean ESD (mGy)**
TOCE		This study	14.94	90.99	394.86
		Wongsanon S., et al. [12]	8.58	121.09	370
		Donald L., et al.[13]	16.8	282.32	1,406
		Vano et al. [14]	-	81.7	500
Femoral angiography		This study	5.9	31.02	100.36
		Vano et al. [14]	-	66.6	-
		Ioaninis A. Tsalafoutas, et al. [15]	2.6	68	257
		McParland [16]	7.2	46.7	-
Diagnostic cerebral angiography	Frontal	This study	13.27	33.11	400.40
	Lateral			35.01	154.77
		Ioaninis A. Tsalafoutas, et al. [15]	4.3	50	349
		McParland [16]	12.1	74.1	220
		Marshall, et al. [17]	-	48.5	150
Therapeutic cerebral angiography	Frontal	This study	40.1	50.15	876.52
	Lateral			97.31	591.93
		Donald L., et al.[13]	92.5	339.76	3791
		McParland [16]	34.1	105	-
		Marshall, et al. [17]	-	122	-

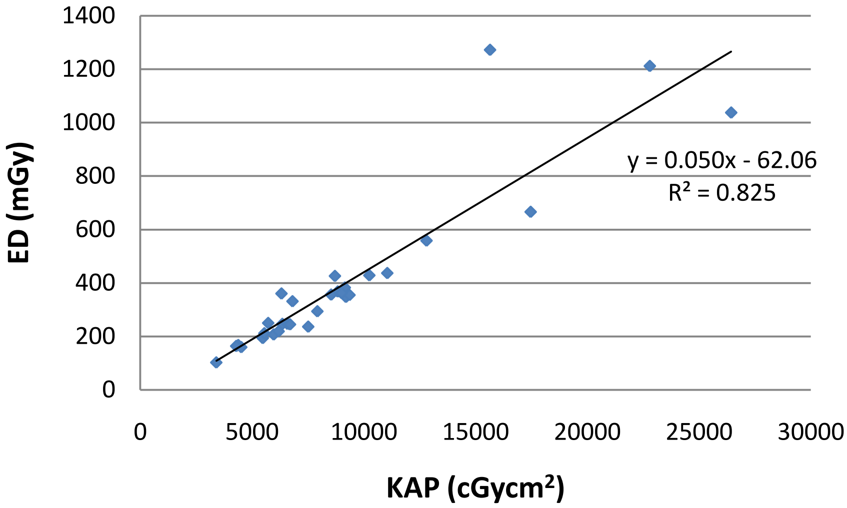

Figure 5.4 Curve of correlation between air kerma area product and entrance skin dose for transarterial oily-chemoembolisation.

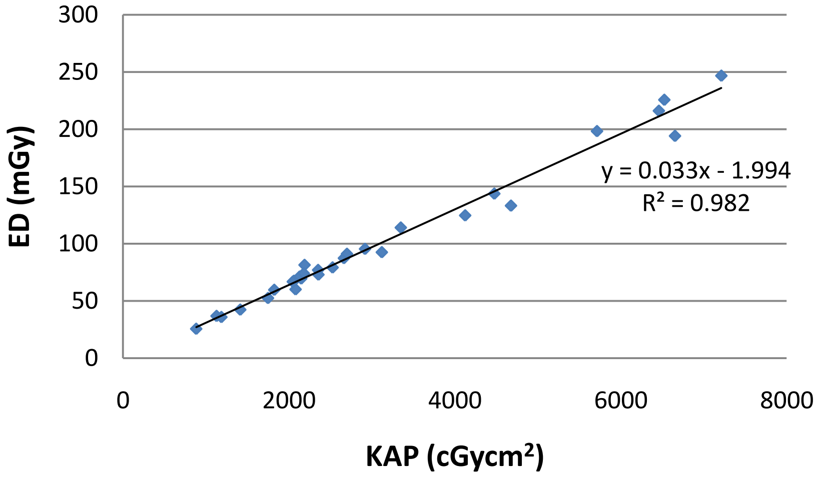

Figure 5.5 Curve of correlation between air kerma area product and entrance skin dose for femoral angiography.

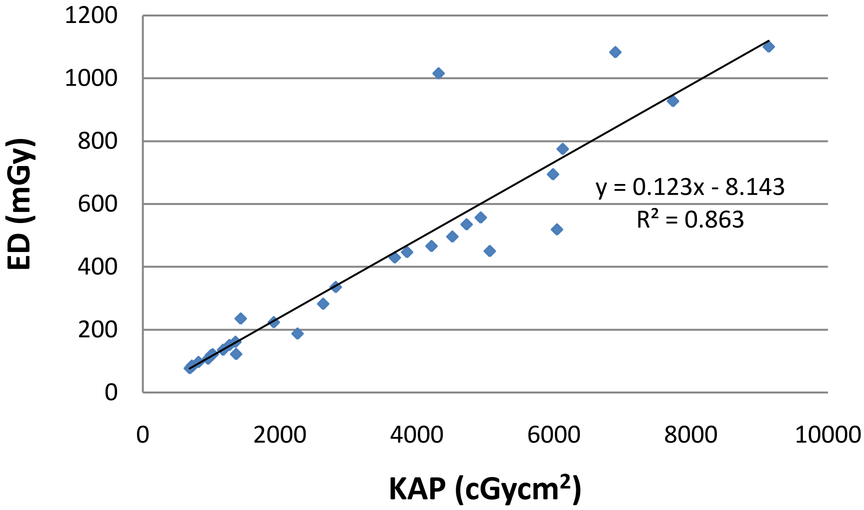

Figure 5.6 Curve of correlation between air kerma area product and entrance skin dose for diagnostic cerebral angiography (frontal).

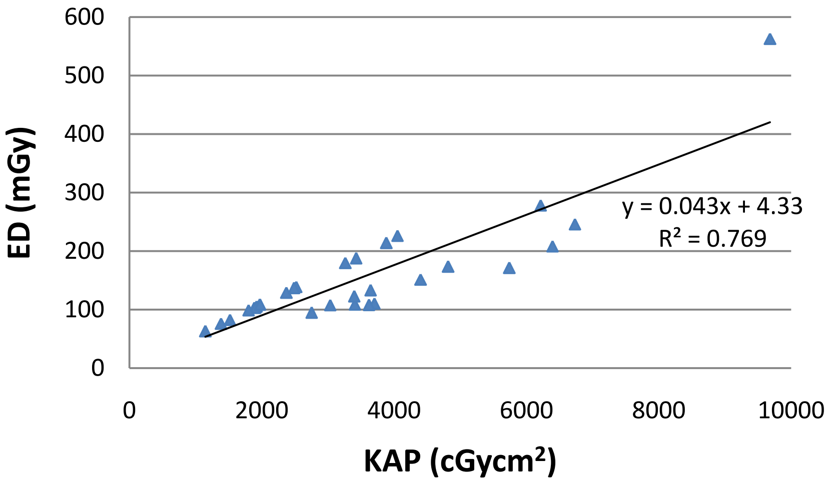

Figure 5.7 Curve of correlation between air kerma area product and entrance skin dose for diagnostic cerebral angiography (lateral).

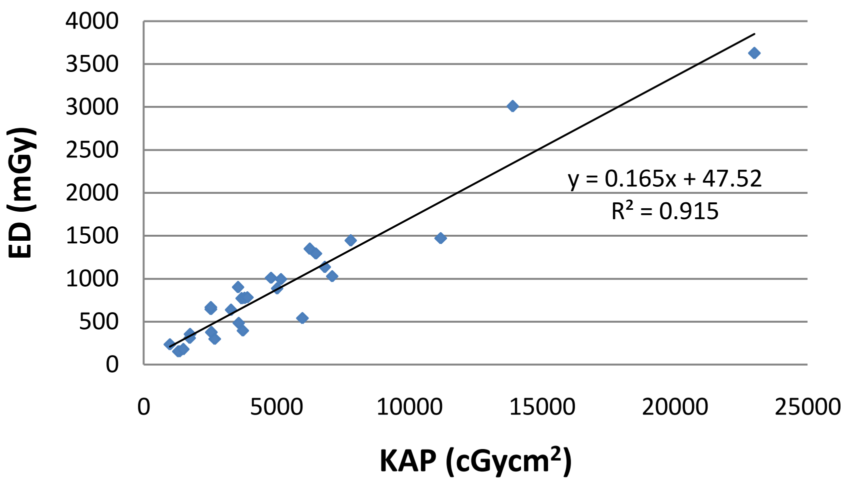

Figure 5.8 Curve of correlation between air kerma area product and entrance skin dose for therapeutic cerebral angiography (frontal).

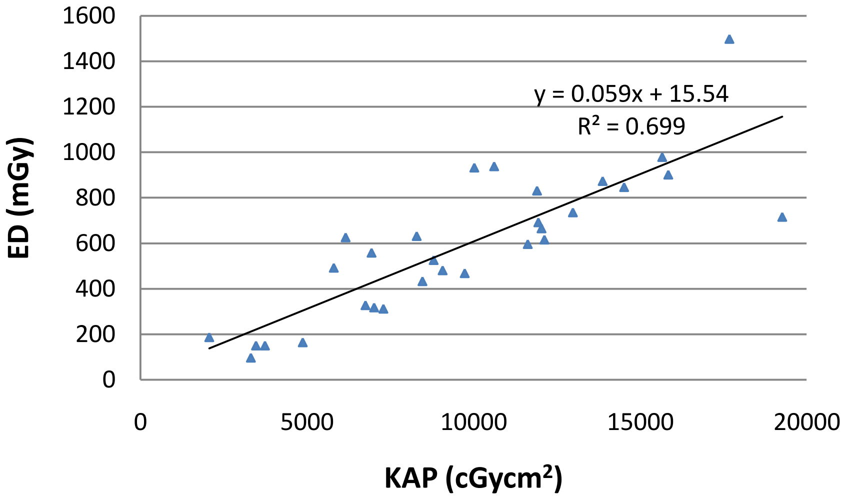

Figure 5.9 Curve of correlation between air kerma area product and entrance skin dose for therapeutic cerebral angiography (lateral).

5.2 Factor affecting to Patient dose

There are many factors that affect to patient dose in interventional radiology. The factors are following.

5.4.1 Tube potential (kV)

Tube potential affects penetrating photon. The high tube potential means more penetrate and lower absorb in medium than low tube potential. Therefore high tube potential is used to reduce patient dose. But, over tube potential can lead to loss image contrast. The suitable high tube potential is used for acceptable image contrast and least patient dose.

5.4.2 Tube current and time (mAs)

Tube current and time is primary factor affect to photon quantity. Tube current and time is proportional to photon quantity. More tube current or time means more photon quantity to create x-ray image but more patient dose.

5.4.3 Number of images

Number of image is related with patient dose. If number of images increase, patient dose will increase proportional. In some case, numbers of images were large because of complication of that case causing high patient dose.

5.4.4 Source to skin distance (SSD)

Source to skin distance is distance between x-ray focal spot and patient skin. Image will be enlargement if patient close to x-ray tube. But patient dose will increase according to inverse square law.

5.4.5 Source to image receptor distance (SID)

Source to image receptor distance is distance between x-ray focal spot and image receptor (image intensifier). Patient dose will increase when increase SID. Because radiation quantity decreases according to inverse square law when increase SID. X-ray system must maintain radiation quantity for keep image quality by increase dose rate.

5.4.6 Pulse mode

Continuous mode is normal mode for fluoroscopy. It emits x-ray all the time during fluoroscopy. Pulse mode is fluoroscopy mode selected for reduce radiation dose. X-ray is emitted in many short time. If many number of x-ray is emitted, the fluoroscopic image will be smooth. If few number of x-ray is emitted, fluoroscope will not be continuous but the patient dose will be decreased.

5.4.7 Image magnification

Magnification will increase patient dose because magnification decreases number of photoelectron on output screen of image intensifier. Tube current is increased to maintain the image brightness.

5.4.8 Collimator

Collimation can reduce the irradiated area. Organ adjacent area of interest will receive lower dose than without collimation. Area of interest will have suitable brightness when cover area with the collimator and the scatter will be reduced.

5.4.9 Patient size

Thick patient cause more absorbed radiation than thin patient. Tube potential and tube current will be increased to maintain the brightness of image and SID will be reduced causing in increasing the patient dose.

CHAPTER VI
CONCLUSION

A radiological procedure such as interventional radiology has been known to give high radiation dose to patients. The mean value of KAP are 9099.41, 3101.87, 3310.97 (Frontal), 3500.68 (Lateral), 5014.75 (Frontal) and 9731.47 (Lateral) $cGycm^2$ for TOCE, femoral angiography, diagnostic cerebral angiography and therapeutic cerebral angiography, respectively. Wide variations were found in KAP and entrance skin dose due to the complicate nature of interventional radiology procedures. The high dose levels can sometimes reach the deterministic risk threshold. These patients require the follow up for monitoring such effects.

KAP meters are now commonly incorporated with the fluoroscopic unit to provide feedback on radiation dose emitted from the x-rays tube. The KAP meter calibrated using proper in-situ protocol can be used as a monitoring tool to warn clinician regarding deterministic risk of radiation such as early transient erythema or epilation. The information of patient dose should be noted in patient chart for follow up in high dose levels or some cases that made interventional radiology more than once.

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APPENDICES

APPENDIX A
QUALITY CONTROL OF TOSHIBA INFINIX VC-i FPD

กรมวิทยาศาสตร์การแพทย์

รายงานผลการตรวจสอบเครื่องเอกซเรย์

เลขที่วิเคราะห์: 0451-004430

สถานที่: โรงพยาบาลรามาธิบดี
270 ถนนพระราม 6 แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพฯ 10400

ชื่อเครื่องเอกซเรย์: TOSHIBA **Model:** Infinix-isiries **S/N:** 99C0642514 **Machine Code:** RAF33138

วัตถุประสงค์: ถ่ายภาพรังสีทั่วไป **Room No.:** 14

วันที่รับตัวอย่าง: 10 มิถุนายน 2551 **วันที่ตรวจสอบ:** 19 สิงหาคม 2551

เจ้าหน้าที่ผู้ตรวจสอบ: นางอนงค์ สิงกาวงไซย์

รายการตรวจสอบ	ค่ามาตรฐาน	ผลการตรวจสอบ
1. ค่ากิโลโวลต์ (kVp)		
1.1 ความเที่ยงตรง (Reproducibility) C.V. %		
ไม่เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 5 %	1.3 %
เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 5 %	N/A
2. การกรองรังสีเอกซ์ (HVL) ที่ 80 kVp	≥ 2.3 mm.Al	4.0 mm.Al
3. ปริมาณรังสี (Radiation output)		
3.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	0.3 %

* N/A = Not Available

วันที่ออกรายงาน 1 กันยายน 2551

Approved by.......................

หน้าที่ 9 ของทั้งหมด 43 หน้า

X-RAY EQUIPMENT BRAND TOSHIBA 150 kV 1000 mA visit 2

RADIOGRAPHIC TUBE

TUBE POTENTIAL VOLTAGE

- kV REPRODUCIBILITY at 80 kV

kV MEASURED	84.77	82.09	83.87	82.48	82.48	82.39

FILTRATION at 80 kV 50 mA 0.007 sec. FCD 60 cm.

NO FILTER = 60 μGy. ADD FILTER 3.5 mm.Al. = 33 μGy.

REPRODUCIBILITY at 80 kV 50 mA 0.007 sec. FCD 60 cm.

MEASURED EXPOSURE (μGy.)	63	63	63	63	63	63

วันที่ออกรายงาน 1 กันยายน 2551

Approved by............

หน้าที่ 10 ของทั้งหมด 43 หน้า

กรมวิทยาศาสตร์การแพทย์

รายงานผลการตรวจสอบเครื่องเอกซเรย์

เลขที่วิเคราะห์: 0451-004431

สถานที่: โรงพยาบาลรามาธิบดี

270 ถนนพระราม 6 แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพฯ 10400

ชื่อเครื่องเอกซเรย์: TOSHIBA **Model:** Infinix-isiries **S/N:** 99C0642514 **Machine Code:** RAF33138

วัตถุประสงค์: ถ่ายภาพบนแผ่นเรืองแสง **Room No.:** 14

วันที่รับตัวอย่าง: 10 มิถุนายน 2551 **วันที่ตรวจสอบ:** 19 สิงหาคม 2551

เจ้าหน้าที่ผู้ตรวจสอบ: นางอนงค์ สิงกาวงไชย์

ผลการตรวจสอบเครื่องเอกซเรย์

รายการตรวจสอบ	ค่ามาตรฐาน	ผลการตรวจสอบ
1. ค่ากิโลโวลต์ (kVp)		
1.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	2.1 %
1.2 ความแม่นยำ (Accuracy) % kVp	≤ 10 %	N/A
2. เครื่องตั้งเวลา (Timer)		
2.1 Exposure Switch	Dead-man Type	มี
2.2 คาบการตั้งเวลา	มี	มี
3. การกรองรังสีเอกซ์ (HVL) ที่ 58 kVp	≥ 1.8 mm.Al	5.2 mm.Al
4. ปริมาณรังสี (Radiation output)		
4.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	2.3 %
5. เครื่องจำกัดลำรังสี (Beam-Limiting Device)		
5.1 เครื่องจำกัดลำรังสี	มี	มี
5.2 การเหลื่อมล้ำของลำรังสี ออกนอกฉากรับภาพที่ระยะ 35 ซม.	ไม่มี	ไม่มี
6. ปริมาณรังสีสะท้อน (Scatter Radiation)	400 μSv ใน 1 สัปดาห์สำหรับเจ้าหน้าที่รังสี	8 μSv ใน 1 สัปดาห์
	20 μSv ใน 1 สัปดาห์ สำหรับบุคคลทั่วไป	≤ 1 μSv ใน 1 สัปดาห์

* N/A = Not Available

วันที่ออกรายงาน 1 กันยายน 2551

Approved by................................

หน้าที่ 11 ของทั้งหมด 43 หน้า

X-RAY EQUIPMENT BRAND TOSHIBA 150 kV 1000 mA visit 2

FLUOROSCOPIC TUBE

TUBE POTENTIAL VOLTAGE

- kV REPRODUCIBILITY at 58 kV

kV MEASURED	61.19	58.96	58.63	57.43	58.54	58.59

FILTRATION at 58 kV 10 mA

MEASURED EXPOSURE NO FILTER = 283 mGy/min. ADD FILTER 3.5 mm.Al. = 178 mGy/min.

REPRODUCIBILITY at 58 kV 10 mA

MEASURED EXPOSURE (mGy/min.)	294	275	286	283	282	280

วันที่ออกรายงาน 1 กันยายน 2551

Approved by.....................

APPENDIX B

QUALITY CONTROL OF TOSHIBA INFINIX VB-i

กรมวิทยาศาสตร์การแพทย์

รายงานผลการตรวจสอบเครื่องเอกซเรย์

เลขที่วิเคราะห์: 0451-004433

สถานที่: โรงพยาบาลรามาธิบดี

270 ถนนพระราม 6 แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพฯ 10400

ชื่อเครื่องเอกซเรย์: TOSHIBA (tube A) **Machine Code:** RAF16251

วัตถุประสงค์: ถ่ายภาพรังสีทั่วไป **Room No.:** 12

วันที่รับตัวอย่าง: 10 มิถุนายน 2551 **วันที่ตรวจสอบ:** 19 สิงหาคม 2551

เจ้าหน้าที่ผู้ตรวจสอบ: นางอนงค์ สิงกาวงไซย์

รายการตรวจสอบ	ค่ามาตรฐาน	ผลการตรวจสอบ
1. ค่ากิโลโวลต์ (kVp)		
1.1 ความเที่ยงตรง (Reproducibility) C.V. %		
ไม่เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 5 %	1.0 %
เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 5 %	N/A
1.2 ความแม่นยำ (Accuracy) % kVp		
ไม่เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 10 %	4.2 %
เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 10 %	N/A
2. การกรองรังสีเอกซ์ (HVL) ที่ 74 kVp	≥ 2.3 mm.Al	3.0 mm.Al
3. ปริมาณรังสี (Radiation output)		
3.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	0.2 %

* N/A = Not Available

วันที่ออกรายงาน 1 กันยายน 2551 Approved by..........................

หน้าที่ 14 ของทั้งหมด 43 หน้า

X-RAY EQUIPMENT BRAND TOSHIBA 150 kV 2000 mA visit 3

RADIOGRAPHIC TUBE

TUBE POTENTIAL VOLTAGE

- kV REPRODUCIBILITY at 74 kV

kV MEASURED	72.97	73.04	72.61	73.36	73.95	73.90

- kV ACCURACY

kV (nominal)	60	74	80	90	100
kV MEASURED	58.61	72.97	78.10	90.99	104.2

FILTRATION at 74 kV 32 mA 0.5 sec. FCD 56 cm.

NO FILTER = 80 μGy. ADD FILTER 3.0 mm.Al. = 40 μGy.

REPRODUCIBILITY at 74 kV 32 mA 0.5 sec. FCD 56 cm.

MEASURED EXPOSURE (μGy.)	77	78	78	78	78	78

วันที่ออกรายงาน 1 กันยายน 2551

Approved by..............................

หน้าที่ 15 ของทั้งหมด 43 หน้า

กรมวิทยาศาสตร์การแพทย์
รายงานผลการตรวจสอบเครื่องเอกซเรย์

เลขที่วิเคราะห์: 0451-004434

สถานที่: โรงพยาบาลรามาธิบดี
270 ถนนพระราม 6 แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพฯ 10400

ชื่อเครื่องเอกซเรย์: TOSHIBA (tube A) **Machine Code:** RAF16251

วัตถุประสงค์: ถ่ายภาพบนแผ่นเรืองแสง **Room No.:** 12

วันที่รับตัวอย่าง: 10 มิถุนายน 2551 **วันที่ตรวจสอบ:** 19 สิงหาคม 2551

เจ้าหน้าที่ผู้ตรวจสอบ: นางอนงค์ สิงกาวงไซย์

ผลการตรวจสอบเครื่องเอกซเรย์

รายการตรวจสอบ	ค่ามาตรฐาน	ผลการตรวจสอบ
1. ค่ากิโลโวลต์ (kVp)		
1.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	0.9 %
1.2 ความแม่นยำ (Accuracy) % kVp	≤ 10 %	4.0 %
2. เครื่องตั้งเวลา (Timer)		
2.1 Exposure Switch	Dead-man Type	มี
2.2 คาบการตั้งเวลา	มี	มี
3. การกรองรังสีเอกซ์ (HVL) ที่ 58 kVp	≥ 1.8 mm.Al	4.9 mm.Al
4. ปริมาณรังสี (Radiation output)		
4.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	0.04 %
5. เครื่องจำกัดลำรังสี (Beam-Limiting Device)		
5.1 เครื่องจำกัดลำรังสี	มี	มี
5.2 การเหลื่อมล้ำของลำรังสี	ไม่มี	ไม่มี
6. ปริมาณรังสีสะท้อน (Scatter Radiation)	400 µSv ใน 1 สัปดาห์สำหรับเจ้าหน้าที่รังสี	8 µSv ใน 1 สัปดาห์
	20 µSv ใน 1 สัปดาห์ สำหรับบุคคลทั่วไป	≤ 1 µSv ใน 1 สัปดาห์

วันที่ออกรายงาน 1 กันยายน 2551

Approved by..................

หน้าที่ 16 ของทั้งหมด 43 หน้า

X-RAY EQUIPMENT BRAND TOSHIBA 150 kV 2000 mA visit 3

FLUOROSCOPIC TUBE

TUBE POTENTIAL VOLTAGE

- kV REPRODUCIBILITY at 56 kV

kV MEASURED	58.68	58.54	58.24	57.22	58.52	58.35

- kV ACCURACY

kV (nominal)	56
kV MEASURED	58.23

REPRODUCIBILITY at 56 kV 10 mA

MEASURED EXPOSURE (mGy/min.)	4.286	4.343	4.205	4.029	0.141	4.055

วันที่ออกรายงาน 1 กันยายน 2551

Approved by..........................

หน้าที่ 17 ของทั้งหมด 43 หน้า

กรมวิทยาศาสตร์การแพทย์

รายงานผลการตรวจสอบเครื่องเอกซเรย์

เลขที่วิเคราะห์: 0451-004436

สถานที่: โรงพยาบาลรามาธิบดี

270 ถนนพระราม 6 แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพฯ 10400

ชื่อเครื่องเอกซเรย์: TOSHIBA (tube B) **Machine Code:** RAF16251

วัตถุประสงค์: ถ่ายภาพรังสีทั่วไป **Room No.:** 12

วันที่รับตัวอย่าง: 10 มิถุนายน 2551 **วันที่ตรวจสอบ:** 19 สิงหาคม 2551

เจ้าหน้าที่ผู้ตรวจสอบ: นางอนงค์ สิงกาวงไซย์

รายการตรวจสอบ	ค่ามาตรฐาน	ผลการตรวจสอบ
1. ค่ากิโลโวลต์ (kVp)		
1.1 ความเที่ยงตรง (Reproducibility) C.V. %		
ไม่เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 5 %	1.0 %
เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 5 %	N/A
1.2 ความแม่นยำ (Accuracy) % kVp		
ไม่เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 10 %	3.5 %
เปลี่ยนมิลลิแอมแปร์ (mA)	≤ 10 %	N/A
2. การกรองรังสีเอกซ์ (HVL) ที่ 74 kVp	≥ 2.3 mm.Al	3.7 mm.Al
3. ปริมาณรังสี (Radiation output)		
3.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	0.9 %

* N/A = Not Available

วันที่ออกรายงาน 1 กันยายน 2551

Approved by..........................

หน้าที่ 19 ของทั้งหมด 43 หน้า

X-RAY EQUIPMENT BRAND TOSHIBA 150 kV 2000 mA visit 3

RADIOGRAPHIC TUBE

TUBE POTENTIAL VOLTAGE

- kV REPRODUCIBILITY at 80 kV

kV MEASURED	83.14	81.66	83.63	81.89	83.63	82.65

- kV ACCURACY

kV (nominal)	80
kV MEASURED	82.77

FILTRATION at 80 kV 10 mAs FCD 60 cm.

NO FILTER = 150 µGy. ADD FILTER 3.0 mm.Al. = 85 µGy.

REPRODUCIBILITY at 80 kV 10 mAs FCD 60 cm.

MEASURED EXPOSURE (µGy.)	153	152	153	152	153	156

วันที่ออกรายงาน 1 กันยายน 2551

Approved by..............................

หน้าที่ 20 ของทั้งหมด 43 หน้า

กรมวิทยาศาสตร์การแพทย์

รายงานผลการตรวจสอบเครื่องเอกซเรย์

เลขที่วิเคราะห์: 0451-004437

สถานที่: โรงพยาบาลรามาธิบดี

270 ถนนพระราม 6 แขวงทุ่งพญาไท เขตราชเทวี กรุงเทพฯ 10400

ชื่อเครื่องเอกซเรย์: TOSHIBA (tube B) **Machine Code:** RAF16251

วัตถุประสงค์: ถ่ายภาพบนแผ่นเรืองแสง **Room No.:** 12

วันที่รับตัวอย่าง: 10 มิถุนายน 2551 **วันที่ตรวจสอบ:** 19 สิงหาคม 2551

เจ้าหน้าที่ผู้ตรวจสอบ: นางอนงค์ สิงกาวงไซย์

ผลการตรวจสอบเครื่องเอกซเรย์

รายการตรวจสอบ	ค่ามาตรฐาน	ผลการตรวจสอบ
1. ค่ากิโลโวลต์ (kVp)		
1.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	0.3 %
1.2 ความแม่นยำ (Accuracy) % kVp	≤ 10 %	1.8 %
2. เครื่องตั้งเวลา (Timer)		
2.1 Exposure Switch	Dead-man Type	มี
2.2 คาบการตั้งเวลา	มี	มี
3. การกรองรังสีเอกซ์ (HVL) ที่ 58 kVp	≥ 1.8 mm.Al	4.9 mm.Al
4. ปริมาณรังสี (Radiation output)		
4.1 ความเที่ยงตรง (Reproducibility) C.V. %	≤ 5 %	0.8 %
5. เครื่องจำกัดลำรังสี (Beam-Limiting Device)		
5.1 เครื่องจำกัดลำรังสี	มี	มี
5.2 การเหลื่อมล้ำของลำรังสี ออกนอกฉากรับภาพที่ระยะ 35 ซม.	ไม่มี	ไม่มี
6. ปริมาณรังสีสะท้อน (Scatter Radiation)	400 µSv ใน 1 สัปดาห์สำหรับเจ้าหน้าที่รังสี 20 µSv ใน 1 สัปดาห์ สำหรับบุคคลทั่วไป	167 µSv ใน 1 สัปดาห์ ≤ 1 µSv ใน 1 สัปดาห์

วันที่ออกรายงาน 1 กันยายน 2551

Approved by..........

หน้าที่ 21 ของทั้งหมด 43 หน้า

X-RAY EQUIPMENT BRAND TOSHIBA 150 kV 2000 mA visit 3

FLUOROSCOPIC TUBE

TUBE POTENTIAL VOLTAGE

- kV REPRODUCIBILITY at 80 kV

kV MEASURED	80.26	80.37	79.99	79.75	80.37	80.40

- kV ACCURACY

kV (nominal)	60	70	80
kV MEASURED	61.05	70.91	80.19

FILTRATION at 80 kV 10 mA

NO FILTER = 3 μGy/min ADD FILTER 3.0 mm.Al. = 2 μGy/min

REPRODUCIBILITY at 80 kV 10 mA

MEASURED EXPOSURE (mGy/min.)	3	3	3	3	3	3

วันที่ออกรายงาน 1 กันยายน 2551

Approved by..........................

หน้าที่ 22 ของทั้งหมด 43 หน้า

BIOGRAPHY

NAME	Mr. Jula Urairat
DATE OF BIRTH	15 Mar 1984
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INSTITUTIONS ATTENDED	Mahidol University, 2006: Bachelor of Science (Radiological Technology)
	Mahidol University, 2012: Master of Science (Medical Physics)
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