การวัดปริมาณรังสียังผลของผู้ป่วยในการตรวจทีโอซีอี (TOCE) ด้วยเครื่องเอกซเรย์ระบบดิจิทัลแฟลทพาเนล

นางสาวพิมณัฏฐา สิทธิพันธ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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THE DETERMINATION OF PATIENT EFFECTIVE DOSE IN TRANSARTERIAL OILY CHEMO EMBOLIZATION (TOCE) PROCEDURE USING DIGITAL FLAT-PANEL SYSTEM

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science Program in Medical Imaging
Department of Radiology
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Thesis Title	THE DETERMINATION OF PATIENT EFFECTIVE DOSE IN TRANSARTERIAL OILY CHEMO EMBOLIZATION (TOCE) PROCEDURE USING DIGITAL FLAT-PANEL SYSTEM
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พิมณัฏฐา สิทธิพันธ์ : การวัดปริมาณรังสีผิวผลของผู้ป่วยในการตรวจทีโอซีอี (TOCE) ด้วยเครื่องเอกซเรย์ระบบดิจิทัลแฟลทพาเนล (THE DETERMINATION OF PATIENT EFFECTIVE DOSE IN TRANSARTERIAL OILY CHEMO EMBOLIZATION (TOCE) PROCEDURE USING DIGITAL FLAT-PANEL SYSTEM) อ.ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.ดร. อัญชลี กฤษณจินดา อ. ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ. นพ. เพิ่มยศ โกศลพันธ์; 89 หน้า.

ในปัจจุบันการตรวจรักษาและวินิจฉัยโรคมะเร็งตับ (TOCE) ได้เข้ามามีบทบาทอย่างมาก เนื่องจาก การตรวจ ทีโอซีอี เป็นการตรวจรักษาผู้ป่วยที่เป็นโรคมะเร็งตับโดยไม่ต้องใช้วิธีการผ่าตัดและมีความเสี่ยงน้อยซึ่งในปัจจุบันได้มีการนำเข้าเครื่องเอกซเรย์ชนิดใหม่นั่นคือ ระบบ บดิจิทัลแฟลตพาเนล (Digital flat-panel system) ซึ่งมีคุณสมบัติที่เหนือกว่าระบบเก่า (Image intensifier system) มาก ในการตรวจทีโอซีอี นั้น จะใช้เวลาในการตรวจรักษานานเป็นผลให้ผู้ป่วยอาจได้รับปริมาณรังสีสูง หากได้รับมากกว่า 2 เกรย์ จะเกิดบาดแผลที่ผิวหนังได้ ในการหาปริมาณรังสีเฉลี่ยและปัจจัยที่มีผลต่อปริมาณรังสีในผู้ป่วยที่ทำการตรวจทีโอซีอี โดยใช้เครื่องวัดปริมาณรังสีที่ผิวของผู้ป่วยเพื่อคำนวณหาปริมาณรังสียังผลที่ผู้ป่วยได้รับ ในการศึกษาจะใช้เครื่องวัดเพื่อหาปริมาณรังสีเฉลี่ยที่ผิวของผู้ป่วยโดยใช้เครื่องวัดรังสีที่เรียกว่า แดปมิเตอร์ (DAP meter) ซึ่งติดอยู่กับหลอดเอกซเรย์ และหาปริมาณรังสีสูงสุดที่ผิวผู้ป่วย โดยใช้เครื่องวัดชนิดโซลิดเสตท (Unfors PSD) ติดที่บริเวณหลังผู้ป่วย 3 จุด ให้ตรงกับตำแหน่งของตับโดยทำการวัดในผู้ป่วยทั้งหมด 69 รายที่ได้รับการตรวจทีโอซีอี ในหน่วยงานรังสีร่วมรักษา ร.พ จุฬาลงกรณ์ สภากาชาดไทย ผลการศึกษาพบว่า ปริมาณรังสีเฉลี่ยที่ผิวหนังของผู้ป่วยที่วัดได้จาก แดปมิเตอร์ มีค่า 222.6$\pm$114.6 เกรย์ซม^2. (22.58-537.43) และปริมาณรังสีสูงสุดที่ผู้ป่วยได้รับมีค่า 1004.2$\pm$ 565 มิลลิเกรย์ (192-3145) และผลจากการคำนวณหาปริมาณรังสียังผลที่ผิวตำแหน่งเหนือตับ เฉลี่ยมีค่า 9.70$\pm$5.27 มิลลิซีเวิร์ท (1.11-23.6) และผลจากการคำนวณหาปริมาณรังสียังผลที่ผิวตำแหน่งเหนือตับสูงสุดมีค่า 10.04 $\pm$ 5.65 มิลลิซีเวิร์ท (1.92 - 3.14) และปริมาณรังสีที่ได้จากตับกลีบซ้าย มีค่า 9.68 มิลลิซีเวิร์ท, ตรงกลางของตับ มีค่า 8.48 มิลลิซีเวิร์ท และตับกลีบขวา มีค่า 5.72 มิลลิซีเวิร์ท ดังนั้นบริเวณที่ผู้ป่วยได้รับรังสีสูงสุดคือ บริเวณตับกลีบซ้าย จากการศึกษาความสัมพันธ์ระหว่างการวัดปริมาณรังสีทั้ง 2 แบบ ผลจาการศึกษา พบว่า ค่า r เท่ากับ 0.82 (95%CI : 3.077-6.03) จากการตรวจ และรักษา ผู้ป่วยที่เป็นมะเร็งตับ โดย ทีโอซีอี พบว่าค่าปริมาณรังสีเฉลี่ยที่ผู้ป่วยได้รับมีค่าน้อยกว่า 2 เกรย์ ซึ่งเป็นค่าปริมาณรังสีที่ก่อให้เกิดผิวหนังเป็นผื่นแดง และพบว่ามีผู้ป่วยจำนวน 2 ราย ที่ได้รับปริมาณรังสีสูงสุดที่ผิวหนังเกินระดับที่กำหนด โดยการวัดจากทั้ง 2 วิธี ปริมาณรังสีที่ได้ คือ 2.34 และ 3.14 เกรย์ ตามลำดับ ในการวัดปริมาณรังสีโดยใช้โซลิดเสตท มีความเหมาะสมและ สะดวกในการวัดปริมาณรังสีที่ผิวของผู้ป่วยเป็นอย่างดี ประโยชน์จากการศึกษานี้เป็นการรายงานถึงปริมาณรังสียังผลเฉลี่ยที่ผู้ป่วยได้รับในการตรวจรักษา เพื่อเป็นการสร้างความตระหนักให้แพทย์ผู้ทำการตรวจและผู้ที่เกี่ยวข้องให้คำนึงถึงปริมาณรังสีที่ผู้ป่วยจะได้รับและปัจจัยที่มีผลต่อปริมาณรังสี เพื่อเป็นการป้องกันอันตรายที่จะก่อให้เกิดอันตรายจากรังสีแก่ผู้ป่วยในการตรวจทีโอซีอี

ภาควิชา	รังสีวิทยา	ลายมือชื่อนิสิต	พิมณัฏฐา สิทธิพันธ์
สาขาวิชา	ฉายาเวชศาสตร์	ลายมือชื่อ อ. ที่ปรึกษาวิทยานิพนธ์หลัก	
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5174800430: MAJOR MEDICAL IMAGING

KEYWORDS: PATIENT EFFECTIVE DOSE/TOCE PROCEDURE/DAP METER/ PATIENT SKIN DOSEMETER PSD

PIMNUTTHA SITTHIPHAN: THE DETERMINATION OF PATIENT EFFECTIVE DOSE IN TRANSARTERIAL OILY CHEMO EMBOLIZATION (TOCE) PROCEDURE USING DIGITAL FLAT-PANEL SYSTEM: THESIS ADVISOR: ASSOC. PROF. ANCHALI KRISANACHINDA, PH.D., THESIS CO-ADVISOR: ASSOC. PROF. PERMYOT KOSOLBHAND, M.D., 89 pp.

Transarterial Oily Chemo Embolization (TOCE) is the procedure producing high dose to both patient and staff. Radiation skin injury to patient was reported by this interventional procedure. Therefore, the avoidance of skin injury during the procedure is needed. The objective of this study is to determine patient effective dose at the skin during TOCE procedure for Hepatocellular Carcinoma (HCC) using a new angiographic unit with a digital flat-panel system and the relationship between the patient effective doses measured by Unfors PSD and the dose area product (DAP) values. The patient effective doses (ED) were determined during TOCE procedure using the digital Flat-panel system, Philips Allura FD 20 at Vascular and Interventional Radiology Unit, King Chulalongkorn Memorial Hospital. The system is equipped with the dose-area-product (DAP) and used to determine the average entrance surface dose (ESD) for each procedure. The peak ESD were evaluated by the solid state dosemeter; Unfors Patient Skin Dosemeters (PSD) placed on patient back at three regions at left, middle, and right portions of the liver. The patients ED were calculated in sixty-nine patients in May-November 2009. The average $\pm$ SD (range) fluoroscopic time was 16.06$\pm$ 11.26 (3.38-59.13) min, average number of frames from DSA (Digital Subtraction Angiography) was 180.81$\pm$94.59 (75-618), the number of frames from x-per CT with the range was 224 -1114. The average ESD determined by DAP was 222.6$\pm$114.6 (22.58-537.43) Gycm^2. The average ESD determined by Unfors PSD was 1004.2$\pm$565.11 (192.6-3145.29) mGy. The average ED determined by DAP was 9.70$\pm$5.27 (1.11 - 23.6) mSv. The peak ED at the skin above the liver determined by Unfors PSD was 10.04$\pm$5.65 (1.93-31.45) mSv. The average of ED at left lobe of liver was 9.68$\pm$5.5 (1.75- 31.4) mSv, the middle lobe was 8.48$\pm$5.13 (1.21 - 28.78) mSv and the right lobe was 5.72+3.55 (0.64 -16.31) mSv. The DAP-to–effective dose conversion factors were 0.043 mSv.Gy^{-1}cm^{-2}. Discussion and Conclusion: The solid state dosemeter is most suitable for entrance surface dose measurement for the small size of detector and easily use. There was no need to estimate the surface area exposed as in DAP method. Two from sixty-nine patients received the entrance surface dose from TOCE procedure using Digital flat-panel system exceeding the threshold for radiation skin injuries which confirmed by both dosemeters.

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Field of Study: Medical Imaging Advisor's Signature Anchali K.

Academic Year: 2009 Co-Advisor's Signature Permyot K.

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LIST OF ABBREVIATIONS

AAPM	American Association of Physicists in Medicine
ACR	American College of Radiologists
ABC	Automatic Exposure Control
Al	Aluminum
a-Se	Amorphous selenium
a-Si	Amorphous silicon
BMI	Body Mass Index
BSF	Back scatter factor
cGy	Centigray
cm	Centimeter
CsI	Cesium Iodide
CsI(Tl)	Cesium Iodide with Thallium doping
CT	Computed Tomography
D	Absorbed dose
DA	Digital Angiography
DAP	Dose Area Product
DF	Digital Fluoroscopy
DSA	Digital Subtraction Angiography
DICOM	Digital Imaging and Communications in Medicine
DQE	Detective Quantum Efficiency
E_A	Exposure Area
ED	Effective dose
EDE	Effective dose equivalent

ESAK	Entrance Surface Air Kerma
ESD	Entrance Skin Dose
ESE	Entrance Skin Exposure
FDA	Food and Drug Administration
FOV	Field of view
Gy	Gray
HVL	Half-Value Layer
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
IQR	Inter Quartile Range
AK	Air Kerma
kVp	Kilo-Volt peak
mAs	Milliampare seconds
mGy	Milligray
mm	Millimeter
mR	Milliroentgen
p	p-value
PMMA	Polymethylmethacrylate
QA	Quality Assurance
QC	Quality Control
R	Roentgen
r	Correlation coefficient
s	Second

SD	Standard Deviation
SID	Source to Image Distance
SPSS	Statistical Package for the Social Sciences
Sv	Sievert
TF	Table attenuation factor
TLD	Thermoluminescent Dosemeter
WHO	World Health Organization

CHAPTER I

INTRODUCTION

1.1 Background and rationale

Interventional radiology has been an essential part of modern patient treatment using fluoroscopically guided interventional radiological procedures for more than 10 years. Radiation-induced skin injury has also been increasingly reported in the literature and received growing attention among the medical community **[1-2]** Therefore; it is important to estimate the patient skin dose and try to reduce it.

Interventional radiology involves in the treatment of various diseases for several decades. Transarterial oily chemo embolization, TOCE, has been used extensively in the non operative treatment of hepatocellular carcinoma (HCC) patient. TOCE has a role in delaying the progression of HCC until a donor liver becomes available. TOCE is an interventional radiology procedure, involves percutaneous access to the hepatic artery usually by puncturing the common femoral artery at the right groin and passing a catheter through the abdominal aorta, through the celiac axis and common hepatic artery, into the feeding arteries supplying the tumors. Chemotherapeutic dose is directed to the tumor following embolization for ischemic effect of the tumors. TOCE is the high dose procedure for both patients and staff. Radiation skin injuries to patients can be caused by this interventional procedure. Therefore, the avoidance of skin injuries during the procedure is needed. Type of radiation effect which occurred is deterministic effects such as cataract, erythema, infertility and etc. The characteristics of deterministic effects were shown as the followings:

1. The tissue or organ damage depends on the absorbed dose.
2. The existence of the threshold dose.

Nowadays, the new digital flat-panel system for angiographic imaging in interventional radiology has been installed at King Chulalongkorn Memorial Hospital in 2008. The usefulness of flat-panel radiography has been evaluated in several literatures **[3-5]**. It has evolved as a new system to deliver high-resolution imaging with high dose efficiency. Digital flat-panel detector offers good image quality, increases sensitivity to X-rays, reduce motion blurring and radiation dose. The patient skin dosemeter (PSD) is a solid state detector and used to measure patient entrance skin dose in real time during fluoroscopy procedures. PSD is a new generation, multifunction, intelligent X-ray meter. It is renowned for its pocket-sized and easy to use meter that improves productivity. The PSD can measure on both continuous or pulsed fluoroscopy and exposures with different waveforms. The human skin can be irradiated with a dose of approximately 2 Gy (200 R) before deterministic effects can occur.

In this study both PSD and DAP methods were used to determine the radiation dose at different purpose. The PSD was used to determine the peak skin dose while the DAP meter was used to determine the average skin dose. Both PSD and DAP meter had been used to determine the effective dose.

1.2 Hypothesis

The range of patient skin dose from TOCE procedure in intervention radiology using digital flat-panel system is less than from the conventional system and threshold level for radiation skin injury.

1.3 Objectives

1 To determine patient effective dose during TOCE for Hepatocellular Carcinoma (HCC) using a new angiographic unit with a digital flat-panel system.

2 To determine the relationship between the effective doses determined by PSD Unfors and the dose area product (DAP) methods.

1.4 Definitions [6]

Dose, absorbed
The amount of energy deposited in any substance by ionizing radiation per unit mass of the substance. It is expressed numerically in rads (traditional units) or grays (SI units).

Dose, equivalent
The product of absorbed dose in tissue multiplied by a quality factor, and then sometimes multiplied by other necessary modifying factors, to account for the potential for a biological effect resulting from the absorbed dose. It is expressed numerically in rems (traditional units) or sieverts (SI units).

Effective dose equivalent
The committed dose equivalent for a given organ multiplied by a weighting factor (see the definition of Weighting Factor)

Deterministic effect
Health effects, the severity of which varies with the dose and for which a threshold exist. Deterministic effects generally result from the receipt of a relatively high dose over a short time period. Skin erythema (reddening) and radiation-induced cataract formation is an example of a deterministic effect (formerly called a nonstochastic effect).

Stochastic effects
Effects that occur by chance and which may occur without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose. In the context of radiation protection, the main stochastic effect is cancer.

Gray
The international system (SI) unit of radiation dose expressed in terms of absorbed energy per unit mass of tissue. The gray is the unit of absorbed dose and has replaced the rad. 1 Gray= 1 joule/kilogram and also equals 100 rad.

Sievert (Sv)
The international system (SI) unit for dose equivalent equal to 1 Joule/kilogram. The sievert has replaced the rem. One sievert is equivalent to 100 rem.

Weighting factor (WT)
A multiplier that is used for converting the equivalent dose to a specific organ or tissue into what is called the "effective dose." The goal of this process was to develop a method for expressing the dose to a portion of the body in terms of an equivalent dose to the whole body that would carry with it an equivalent risk in terms of the associated fatal cancer probability. It applies only to the stochastic effects of radiation.

Scattered radiation
Radiation that, during its passage through a substance, has been changed in direction. It may also have been modified by a decrease in energy. It is one form of secondary radiation.

CHAPTER II

REVIEW OF RELATED LITERATURES

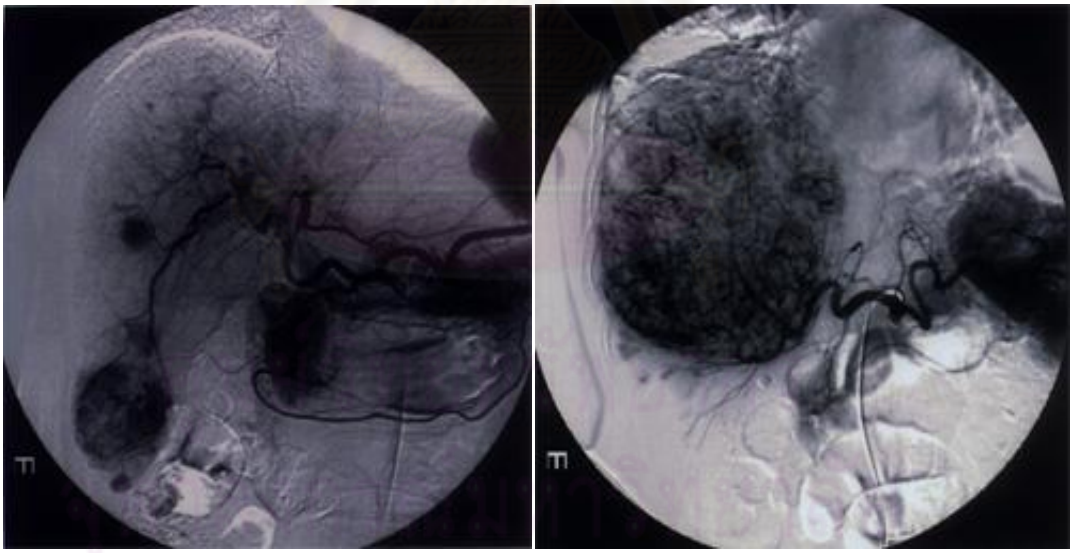
2.1 Theory

2.1.1 Transarterial oily chemo embolization (TOCE)

Transarterial oily chemo embolization (TOCE) has been used extensively in the palliative treatment of unrespectable HCC (hepatocellular carcinoma), one of the most common malignancies worldwide.

In the west, the most common causes are an alcoholic and viral hepatitis (C). The standard treatment for HCC is surgical resection, which has a 60% 5 year survival. In case of unresectable tumor or marginal liver function, the current treatment of choice is orthotopic liver transplantation. Due to the scarcity of organ donors and to the multiple carcinomas these patients have, many die while on the transplant list. TOCE has a role in delaying the progression of HCC until a donor liver becomes available.

The lifespan for a patient with unresectable HCC could reasonably be extended for 1-2 years with continuing TOCE (although the exact benefit would depend heavily on the patient's medical condition)



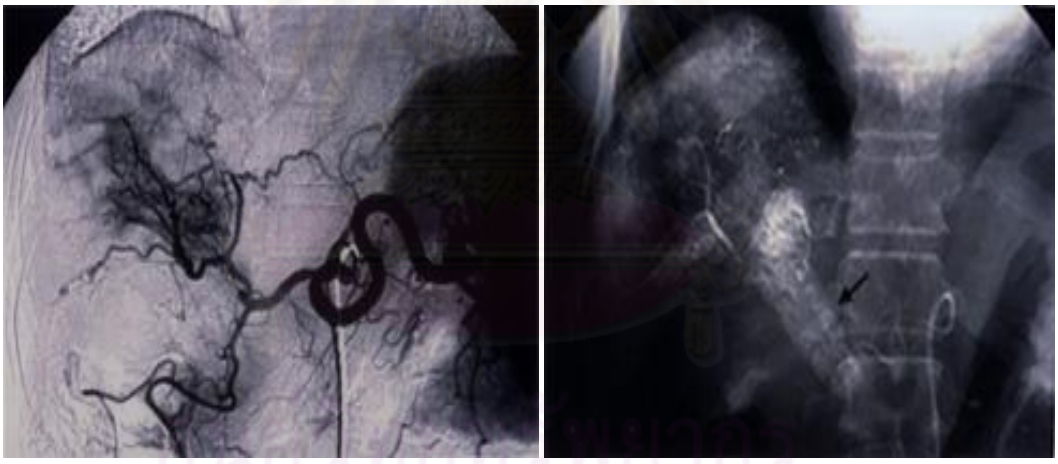
A B

Figure 2.1 Images from Transarterial oily chemo embolization (TOCE) procedures, (A) Multi nodular tumors stain in right hepatic lobe of the patient in TOCE procedure. (B) The patient with large HCC supplied by multiple extrahepatic collaterals and accessory left gastric and hepatic falciform arteries from the left hepatic artery.

2.1.1.1 Transarterial oily chemo embolization (TOCE) Procedure

TOCE is an interventional radiology procedure. The procedure involves gaining percutaneous access to the hepatic artery, usually by puncturing the common femoral artery in the right groin and passing a catheter through the abdominal aorta, through the celiac axis and common hepatic artery, into the proper hepatic artery (which supplies the liver). The interventional radiologist performs an arteriogram to identify the branches of the hepatic artery supplying the tumor(s) and threads smaller catheters into these branches. This is done to maximize the amount of the chemotherapeutic dose directed to the tumor (Figure 2.2). When a blood vessel supplying tumor has been selected, alternating aliquots of the chemotherapy dose and of embolic particles are injected through the catheter. The total chemotherapeutic dose may be given in one vessel's distribution, or it may be divided among several vessels supplying the tumor(s).

TOCE derives its beneficial effect by two methods. Since most tumors are supplied by the hepatic artery, arterial embolization interrupts their blood supply and postpones growth until replaced by neovascularity. Secondly, focused administration of chemotherapy allows a higher dose to the tissue while simultaneously reducing systemic exposure, which is typically the dose limiting factor. This effect is potentiated by the fact that the chemotherapeutic drug is not washed out from the tumor bed after embolization.



A B

Figure 2.2 Transarterial oily chemo embolization (TOCE) procedures, (A) The smaller catheters into these branches the hepatic artery supplying the tumor, (B) Simple radiography taken after chemoembolization shows satisfactory lipiodol retention in the main portal tumour thrombi (arrow).

2.1.1.2 Risk and complications

The goal of the interventional radiology procedure is to kill tumor but a risk of hemorrhage and/or damage to blood vessels could occur. The resulting necrotic material releases cytokines and other inflammatory chemicals into the blood stream, and patients are routinely kept in a hospital for several days following the procedure. A concerning complication of TOCE is the development of an abscess within the necrotic tissue. This is a potentially fatal event.

From the biological effects of radiation on human body, radiation effects are generally divided into two categories: "Deterministic effects" and "Stochastic effects". A non-stochastic or deterministic health effect has a severity that is dependent on dose and is believed to have a threshold level for which below the level, no effect is seen. Stochastic health effects occur by chance, without a threshold level of dose. The probability is proportional to the dose and the severity is independent of the dose, such as cancer and genetic effects.

2.1.1.3 Deterministic effects

Based on a large number of experiments involving animals, it was discovered that severity of certain effects on human beings will increase with increasing doses. There exists a certain level, the "threshold", below which the effect will be absent. This kind of effects is called "deterministic effects".
Characteristics of deterministic effects:

- Damage depends on absorbed dose
- Threshold exists

Example: cataract, erythema, infertility etc.

Deterministic effects and dose relationship

Severity of deterministic effects depends on dose. However, thresholds exist, only above which the effects will occur. The International Commission on Radiological Protection (ICRP) considers that if the annual radiation doses to the lens of the eyes of radiation workers are restricted to 150 mSv (equivalent to 150 mGy for X-ray), cataract is unlikely to occur during his/her life assuming a working period of 50 years. For other major organs, the annual dose limits for preventing deterministic effects are as follows.

Table 2.1 Threshold for deterministic effects (Sv)

Threshold for deterministic effects (Sv)			
Exposed Organ	Effects	One single absorption (Sv)	Prolong absorption (Sv-year)
testis	permanent infertility	3.5 - 6.0	2
ovary	permanent infertility	2.5 - 6.0	> 0.2
Lens of eyes	milky of lens	0.5 - 2.0	> 0.1
	cataract	5.0	> 0.15
Bone marrow	Blood forming deficiency	0.5	> 0.4

(Source: 1990 Recommendations of the International Commission on Radiological Protection (ICRP Publication No. 60)) [7]

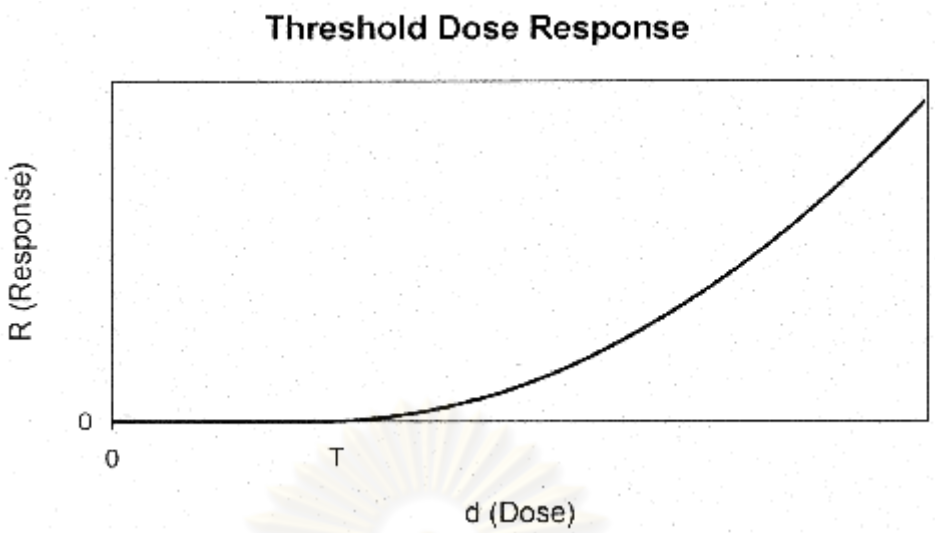


Figure 2.3 The threshold for deterministic effects (Kenny S. Crump ICF-Kaiser, Ruston, LA)

2.1.1.4 Stochastic effects

The severity of stochastic effects is independent of the absorbed dose. Under certain exposure conditions, the effects may or may not occur. There is no threshold and the probability of having the effects is proportional to the dose absorbed.
Characteristics of stochastic effects:

- Severity is independent of absorbed dose
- Threshold does not exist
- Probability of occurrence depends on absorbed dose

Example: radiation induced cancer, genetic effect

As stochastic effects of radiation have no thresholds and can cause cancers or genetic modifications, of which the curing rates are rather low to date, they become a major subject of research in radiation protection.

2.1.2 Fluoroscopy

Fluoroscopy is an imaging technique commonly used by radiologists to obtain real-time moving images of the internal structures of a patient through the use of a fluoroscope. In its simplest form, a fluoroscope consists of an x-ray source and fluorescent screen between which a patient is placed. However, modern fluoroscopes couple the screen to an x-ray image intensifier and CCD video camera allowing the images to be played and recorded on a monitor.

The use of x-rays, a form of ionizing radiation, requires that the potential risks from a procedure be carefully balanced with the benefits of the procedure to the patient. While radiologists try to use low dose rates during fluoroscopic procedures, the length of a typical procedure often results in a relatively high absorbed dose to the

patient. Recent advances include the digitization of the images captured and flat-panel detector systems can reduce the radiation dose to the patient.

Because fluoroscopy involves the use of x rays, all fluoroscopic procedures pose a potential health risk to the patient. Radiation doses to the patient depend greatly on the size of the patient as well as length of the procedure, with typical skin dose rates as 20-50 mGy/min. Exposure times vary on the procedure being performed, and the time up to 75 minutes have been documented. Because of the length of some procedures, in addition to standard cancer-inducing stochastic radiation effects, deterministic radiation effects have also been observed from mild erythema, equivalent of a sun burn, to more serious burns.

A study has been performed by the Food and Drug Administration (FDA) entitled Radiation-induced Skin Injuries from Fluoroscopy **[8]** with an additional publication to minimize further fluoroscopy-induced injuries, Public Health Advisory on Avoidance of Serious X-Ray-Induced skin Injuries to patients during Fluoroscopically-Guided Procedures. **[1]**

2.1.2.1 Fluoroscopic equipment

The first fluoroscope consisted of an x-ray source and fluorescent screen between which the patient would be placed. As the x rays pass through the patient, they are attenuated by varying amounts as they interact with the different internal structures of the body, casting a shadow of the structures on the fluorescent screen. Images on the screen are produced as the unattenuated x- rays interact with atoms in the screen through the photoelectric effect, giving their energy to the electrons. While much of the energy given to the electrons is dissipated as heat, a fraction of it is given off as visible light, producing the images. Early radiologists would adapt their eyes to view the dim fluoroscopic images by sitting in darkened rooms, or by wearing red adaptation goggles.

2.1.2.2 Image intensifier

The invention of x-ray image intensifiers in the 1950s allowed the image on the screen to be visible under normal lighting conditions, as well as providing the option of recording the images with a conventional camera. Subsequent improvements included the coupling of, at first, video cameras and, later, CCD cameras to permit recording of moving images and electronic storage of still images.

Modern image intensifiers no longer use a separate fluorescent screen. Instead, a cesium iodide phosphor is deposited directly on the photocathode of the intensifier tube. On a typical general purpose system, the output image is approximately 10^5 times brighter than the input image. This *brightness gain* comprises a *flux gain* (amplification of photon number) and *minification gain* (concentration of photons from a large input screen onto a small output screen) each of approximately 100. This level of gain is sufficient that quantum noise, due to the limited number of x-ray photons, is a significant factor limiting image quality. Image intensifiers are available with input diameters of up to 45 cm, and resolution of approximately 2-3 line pairs mm^{-1}

2.1.2.3 Flat-panel detector

The introduction of flat-panel detectors allows for the replacement of the image intensifier in fluoroscope design. Flat panel detectors offer increased sensitivity to X-rays, and therefore have the potential to reduce patient radiation dose. Temporal resolution is also improved over image intensifiers, reducing motion blurring. Contrast ratio is also improved over image intensifiers: flat-panel detectors are linear over very wide latitude, whereas image intensifiers have a maximum contrast ratio of about 35:1. Spatial resolution is approximately equal, although an image intensifier operating in 'magnification' mode may be slightly better than a flat panel.

Flat panel detectors are considerably more expensive to purchase and repair than image intensifiers, so their uptake is primarily in specialties that require high-speed imaging, e.g., vascular imaging and cardiac catheterization.

2.1.3. Basic principle of flat panel imaging detectors

The principle of the flat-panel detector is illustrated in figure 2.4.

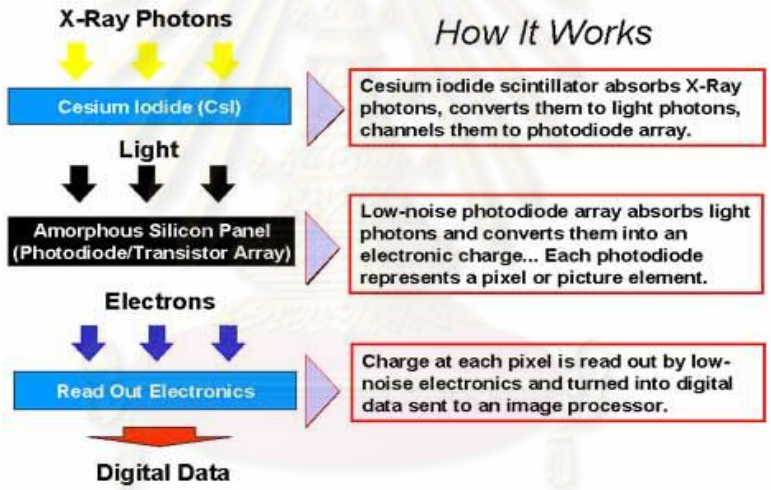


Figure 2.4 The principle of the digital indirect conversion detector (Principle of the GE Revolution™ Digital Flat Panel Detector)

The cesium iodide (CsI) scintillator absorbs x-ray photons, converting their energy into light photons emission. This light is then channeled toward the amorphous silicon photodiode array where it causes the charge of each photodiode to be depleted in proportion to the light it receives. Each of these photodiodes is a picture element (pixel); the spatial sampling of the image, which is the first step in image digitization, is thus performed exactly where the image is formed, whereas it is realized almost at the end of the chain in an Image Intensifier. The electronic charge required to recharge each photodiode is then read by ultra-low-noise proprietary electronics and converted into digital data that are then sent to a real-time image processor. In the cardiac system, over 30 million pixels per second are read out, processed, and displayed in real time. The flat panel digital detector consists of a two-dimensional array of amorphous silicon photodiodes and thin-film transistors (TFTs), all deposited on a single substrate.

Utilizing thin film technology similar to that used in the fabrication of integrated circuits, layers of amorphous silicon and various metals and insulators are deposited on a glass substrate to form the photodiodes and TFTs matrix, as well as the interconnections, and the contacts on the edges of the panel.

2.1.4 Direct versus indirect conversion

Electronic x-ray detectors can be divided into two classes—direct methods and indirect methods (Figure2.5). Direct-conversion detectors have an x-ray photoconductor, such as amorphous selenium, that directly converts x-ray photons into an electric charge. Indirect-conversion detectors have a two-step process for x-ray detection; a scintillator is the primary material for x-ray interaction. When x rays strike the scintillator, the x-ray energy is converted into visible light, and that light is then converted into an electric charge by means of photodetectors such as amorphous silicon photodiode arrays or CCDs.

In both direct- and indirect-conversion detectors, the electric charge pattern that remains after x-ray exposure is sensed by an electronic readout mechanism, and analog-to-digital conversion is performed to produce the digital image.

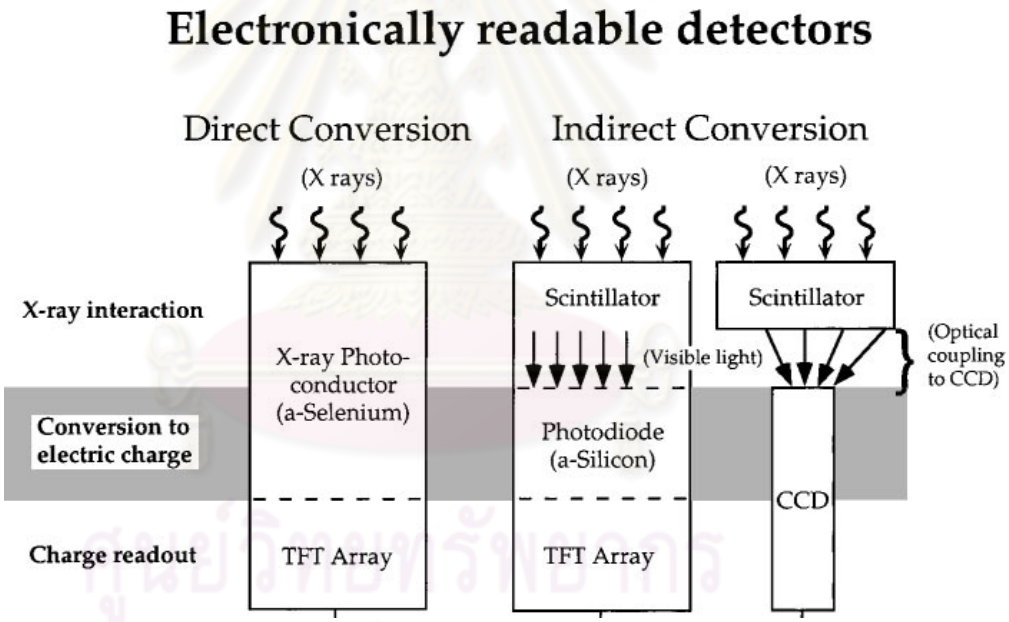


Figure2.5 Direct versus Indirect conversion **(**Chotas, H. G. et al. Radiology 1999)

Direct-readout electronic x-ray detectors use either a direct technique or an indirect technique for converting x- rays into an electric charge as in figure 2.5. Direct-conversion detectors have an x-ray photoconductor, such as amorphous selenium, that converts x-ray photons into an electric charge directly, with no intermediate stage. Indirect-conversion devices have a scintillator that first converts x rays into visible light.

That light is then converted into an electric charge by using an amorphous silicon photodiode array or a CCD. Thin-film transistor (*TFT*) arrays may be used in both direct- and indirect-conversion detectors.

2.1.5 Detective quantum efficiency, DQE

The DQE allows the comparison of imaging detectors which may use fundamentally different technology on an absolute basis. DQE is becoming the accepted "figure-of-merit" for scientific and commercial purposes. There is still much debate as how to standardize the measurement protocols for measuring the various types of digital x-ray detectors now available.

The measurements, currently performed, only deal with the detector performance and do not account for the complex image processing or display manipulations of an imaging system.

It is, therefore important to appreciate that a system with a higher DQE will not necessarily produce better images and DQE strongly depends on the measurement conditions employed. Currently, DQE measurements generally only deal with the x-ray image detector under set experimental conditions and do not account for image processing or display stages.

A higher DQE detector does not necessarily guarantee better image quality, as the detector is only one component of modern cardiac and vascular imaging systems.

DQE definition

$$\mathrm{DQE} = \frac{SNR^2\mathrm{OUT}}{SNR^2\ IN} \qquad 2.1$$

The simplest definition of detective quantum efficiency can be stated in the formula 2.1. It shows that the DQE is the ratio of the output SNR squared to the input SNR squared.

DQE graph

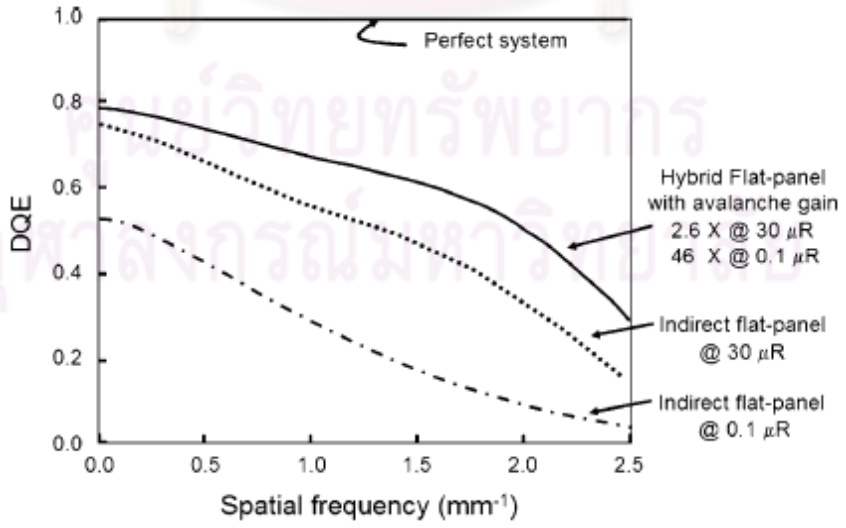


Figure 2.6 DQE comparison of prototype hybrid system and conventional flat panel (indirect) detector systems at low (0.1 μR) and high (30 μR) incident exposures are plotted (data extracted from references **[9, 10]**)

2.1.6 Dosmetric quantities [11]

2.1.6.1The 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 surface. Only the radiation incident on the patient or phantom and not the backscattered radiation is included. Unit: J/kg. The name for the unit of kerma is gray (Gy).

2.1.6.2 Entrance surface dose (ESD)

The entrance surface dose, Ki, is defined as the absorbed dose in air at the point of intersection of the x-ray beam axis with the entrance surface of the patients, Ke, including back-scattered radiation, B, and a well defined equation 2.2

$$Ke = KiB \qquad 2.2$$

2.1.6.3 Air kerma–area product (Dose 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 thus:

$$P_{KA} = \int_A K\,(x, y)dxdy \qquad 2.3$$

Unit: J·kg–1·m^2. If the special name gray is used, the unit of air kerma–area product is Gy·m^2. The air kerma–area product (Dose area product) has the useful property that it is approximately invariant with distance from the X ray tube focus (when interactions in air and extrafocal radiation can be neglected), 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.

2.1.7 Dosmetric quantities related to stochastic and deterministic effects

2.1.7.1Organ and tissue dose

The mean absorbed dose in a specified tissue or organ is given the symbol D_T in ICRU 51 **[12].** It is equal to the ratio of the energy imparted, $\acute{\varepsilon}_T$, to the tissue or organ to the mass, m_T, of the tissue or organ, thus

$$D_T = \frac{\acute{\varepsilon} T}{m\ T} \qquad 2.4$$

The mean absorbed dose in a specified tissue or organ is sometimes simply referred to as the organ dose.

2.1.7.2 Equivalent dose

The equivalent dose, H_T, to an organ or tissue, T, is defined in ICRP 60 and ICRU 51. For a single type of radiation, R, it is the product of a radiation weighting factor, W_R, for radiation R and the organ dose, D_T, thus:

$$H_T = W_R D_T \quad 2.5$$

Unit: J/kg. The special name for the unit of equivalent dose is sievert (Sv). The radiation weighting factor, W_R, allows for differences in the relative biological effectiveness of the incident radiation in producing stochastic effects at low doses in tissue or organ, T. For X-ray energies used in diagnostic radiology, W_R is taken to be unity.

2.1.7.3 Effective dose (ED)

The effective dose, *E*, is defined in ICRP 60 and ICRU 51**.** It is the sum over all the organs and tissues of the body of the product of the equivalent dose, H_T, to the organ or tissue and a tissue weighting factor, W_T, for that organ or tissue, thus:

$$ED = \sum_T W_T H_T \quad 2.6$$

The tissue weighting factor, W_T, for organ or tissue T represents the relative contribution of that organ or tissue to the total detriment arising from stochastic effects for uniform irradiation of the whole body.

Unit: J/kg. The special name for the unit of effective dose is sievert (Sv).The sum over all the organs and tissues of the body of the tissue weighting factors, W_T, is unity.

Table 2.2 W_T – new recommendations from Impact of the new ICRP recommendations on external radiation protection dosimetry. **[13]**

ORGAN	ICRP26	ICRP60	ICRP103
Gonads	0.25	0.20	0.08
Bone marrow (red)	0.12	0.12	0.12
Lung	0.12	0.12	0.12
Breast	0.15	0.05	0.12
Thyroid	0.03	0.05	0.04
Bone surfaces	0.03	0.01	0.01
Remainder	0.30	0.05	0.12
Colon	-	0.12	0.12
Stomach	-	0.12	0.12
Bladder	-	0.05	0.04
Liver	-	0.05	0.04
Oesophagus	-	0.05	0.04
Skin	-	0.01	0.01
Salivary glands	-	-	0.01
Brain	-	-	0.01

(Source: 2007 Recommendations of the International Commission on Radiological Protection (ICRP Publication No. 103), Centre for Radiation, Chemical and Environmental Hazards, Health Protection Agency (HPA))

2.1.8 Dosimetric equipment

Doses from diagnostic radiological examinations are small and usually do not approach thresholds for deterministic effects. Exceptions are found for interventional procedures in radiology and cardiology that may involve high doses to the patient's skin. Severe skin injuries have been documented. Even ignoring the high doses found for interventional procedures, it needs to be realized that the greatest source of exposure of the population to artificial ionizing radiation is from diagnostic radiology.

The doses delivered in diagnostic radiological procedures should therefore be accurately determined in order to maintain a reasonable balance between image quality and patient exposure. Dosimetric methods should be used to ensure appropriate levels of accuracy and long term stability.

2.1.8.1 Solid state detector

Dosimeters with thermoluminescence and semiconductor detectors are considered here. Real time measurements may be conveniently accomplished with semiconductor dosimeters; the small size of thermoluminescence dosimeters (TLDs) allows their application for conducting measurements on patients. Traditionally, the main disadvantage of these devices has been their energy dependence of response which differs considerably from that of ionization chambers. These types of dosimeter have found many applications in postal audits or in routine clinical measurements in hospitals. They are not used for calibrations of other dosimeters in SSDLs.

2.1.8.2 Patient skin dosimeter (PSD)

Unfors PSD is a solid state detector and used to measure patient entrance skin dose in real time during fluoroscopy procedures.

Specifications general of Unfors PSD

The Unfors PSD sensors have been specially designed to meet the needs of real-time dose measurements on patients. Sensor characteristics give accurate information to the user on when injury risk is imminent as shown in table 2.3.and the energy dependent as shown in figure 2.7.

Table 2.3 Specifications general of Unfors PSD

Specifications General	
Dose range	1 μGy - 9999 Gy 100 μR - 9999 R
Start trig level	10 μGy/s, 60 mR/min
Stop trig level:	5 μGy/s, 30 mR/min
Maximum dose rate:	100 mGy/s, 600 R/min
Reproducibility:	1 %

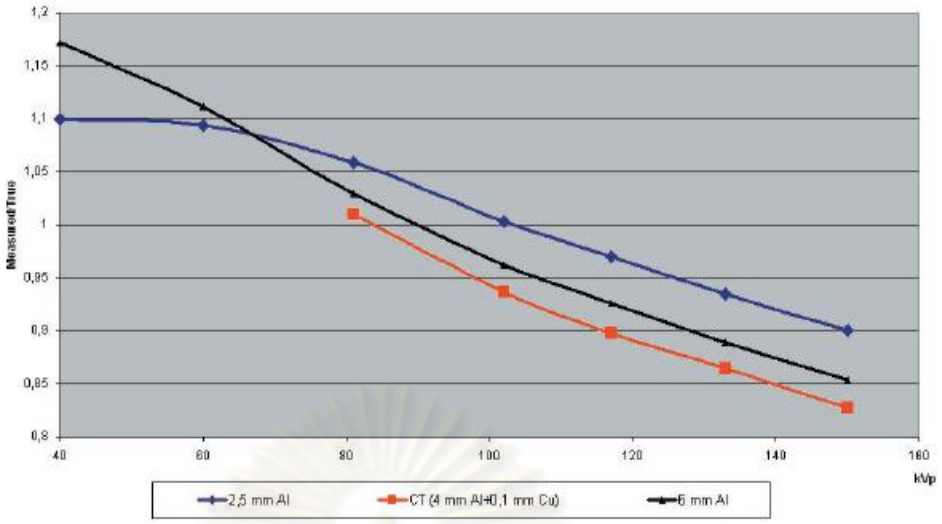


Figure 2.7 The Energy dependence for Unfors PSD (www.unfors.com)

Sensor characteristics

The sensor is calibrated to ESD (Entrance Skin Dose) at 90 kVp in Gy and the energy dependence is < ±10 % for the energy range 60-110 kVp (<15% for energy range 40-140 kVp) at a tube filtration of 6 mmAl as shown table 2.4.

Table 2.4 Sensor characteristics of Unfors PSD

	Sensor
Expanded uncertainty:	± 6 % at calibration point 90 kVp
Angular dependence	± 5 % for 45°
	± 10 % for 75°
Bandwidth	2.4 Hz, 3 dB
Energy dependence:	± 10 % (60 - 120 kVp)
	± 15 % (40 - 150 kVp) at 6 mm Al
Temp. dependence	Negligible
Pressure dependence	Negligible
Size (H x W x L)	4 x 15 x 15 mm,0.15 x 0.60 x 0.60 in
Cable length	2.25 m, 90 in

The Angular dependence as shown in figure 2.8 ,the Unfors PSD Entrance Skin Dose response at 70 kVp, 100 cm FSD and 30 x 30 cm field size. The sensor was mounted on an ISO body phantom which is radially and axially rotated in the radiation field. The cable end of the detector is at 90°.

Unfors PSD sensors have a small footprint and are easy to position on several places on the patient's body.

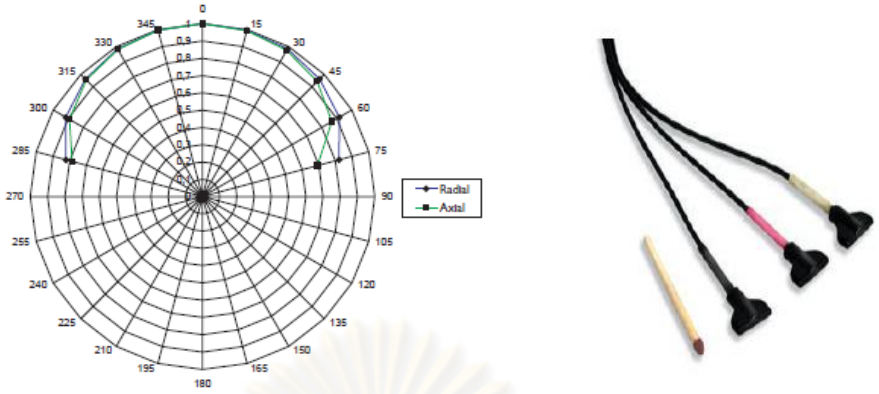


Figure 2.8 Angular dependence and small sensors of Unfors PSD (www.unfors.com)

The patient's skin dose was measured by Unfors patient skin dosimeters (PSD) behind the left, middle, and right portions of the liver for the new digital flat-panel angiographic imaging system during TOCE for HCC.

2.1.8.3 Dose area product (DAP)

DAP is the transmission ionization chambers measuring the dose area during fluoroscopy. The irradiation geometry (field size, focus skin distance, projection) and irradiation time vary individually from patient to patient. If the detector mounted on the tube housing is 'transparent' to X rays, then both focal and extra focal radiation will pass through its sensitive volume. If attenuation in the air can be neglected, those X-rays transmitted through the detector will pass every plane perpendicularly to the beam central axis downstream of the beam. If the integration of air kerma over beam area is extended over the entire plane, the dose–area product will be invariant with distance from the X-ray tube provided the beam is contained by the DAP meter. In this situation, the dose–area product offers a convenient quantity for monitoring patient exposure.

The transmission ionization chamber generally consists of layers of PMMA coated with conductive material. Graphite, a commonly used coating material, is close to air equivalent and introduces low energy dependence for air kerma measurements. Graphite coating is, however, inconvenient in transmission chambers since it is non-transparent to light. Light transparent materials are therefore mostly used.

These materials contain elements of high atomic number such as indium and tin, giving rise to relatively strong energy dependence compared to graphite coated chambers.

In this study, the quantity of interest is the dose–area product so a term DAP meter is used throughout. Requirements on performance of this equipment are set in IEC 60580 **[14].**

2.2 Review of related literature

Shigeru Suzuki et al **[15],** studied the radiation dose to patients and radiologists during transcatheter arterial embolization: comparison of a digital flat-panel system and conventional unit in the year 2005. The patients' skin doses were evaluated with thermoluminescent dosimeters (TLD) at behind the left, middle, and right portions of the liver.

The new digital flat-panel system for angiographic imaging can reduce the radiation dose to patients' skin during TAE for HCC as compared with the conventional system. The maximal skin dose to the patients was significantly lower with the new unit than with the conventional unit.

R Ruiz Cruces et al **[16],** studied the estimation of effective dose in some digital angiographic and interventional procedures. The objective of this study was to provide dose data for some digital angiographic and interventional procedures. Abdominal angiography, arteriography of lower limbs, biliary drainage, embolization of spermatic vein and nephrostomy have been investigated. All the procedures were performed using digital equipment. Value of DAP and effective dose were 30 $Gycm^2$ and 6.2 mSv for arteriography of lower limbs and 150 $Gycm^2$ and 38.2 mSv for biliary drainage as in table 2.5.

Table 2.5 The average of effective doses in some digital angiographic and interventional procedures. **[16]**

Procedure	E(mSv)			E/film	E/min
	R	Fl	Total	(mSv f-1)	(mSv min-1)
Abdominal angiography	3.1	5.1	8.2	0.1	0.8
Arteriography of lower limbs	3.8	2.4	6.2	0.1	0.6
Drainage biliary	1.8	36.4	38.2	0.5	1.1
Embolization of spermatic vain	0.4	16.9	17.3	0.1	0.7
Nephrostomy	0.9	12.7	13.6	0.3	1.0

E, effective dose; E/fime, effective dose per film; E/min, effective dose per minute; R, radiography; Fl, fluoroscopy

In September 1994, the Food and Drug Administration (FDA) of the United States issued a public health advisory entitled "Avoidance of Serious x-ray Induced Skin Injuries to Patients During Fluoroscopy-Guided Procedures" **[8]**.

The advisory recommended,among several items, that information be recorded in the patient record which permits estimation of absorbed dose to the skin. The purpose of the recommendation is to encourage identification of the skin irradiated at levels of absorbed dose that approach or exceed a threshold for injury **[16]**.

A threshold level of concern is 2 Gy for the onset of transient erythema and 3Gy for hair loss as in Table 2.6.

Table 2.6 Radiation induced skin injuries adapted from L.K. Wagner et al **[16]**

Injury	Thresold Dose to skin(Gy)	Weeks to Onset
Early transient erythema	2	<<1
Temporary epilation	3	3
Main erythema	6	1.5
Permanent epilation	7	3
Dry desquamation	10	4
Invasive fibrosis	10	
Dermal atrophy	11	>14
Telangiectasis	12	>52
Moist desquamation	15	4
Late erythema	15	6-10
Dermal necrosis	18	>10
Secondary ulceration	20	>6

CHAPTER III

RESEARCH METHODOLOGY

3.1 Research design

This research is an observational descriptive design study to determine patient effective dose from Transarterial oily chemo embolization procedure in interventional radiology. The procedures are as the following steps as in figure 3.1.

3.2. Research design model

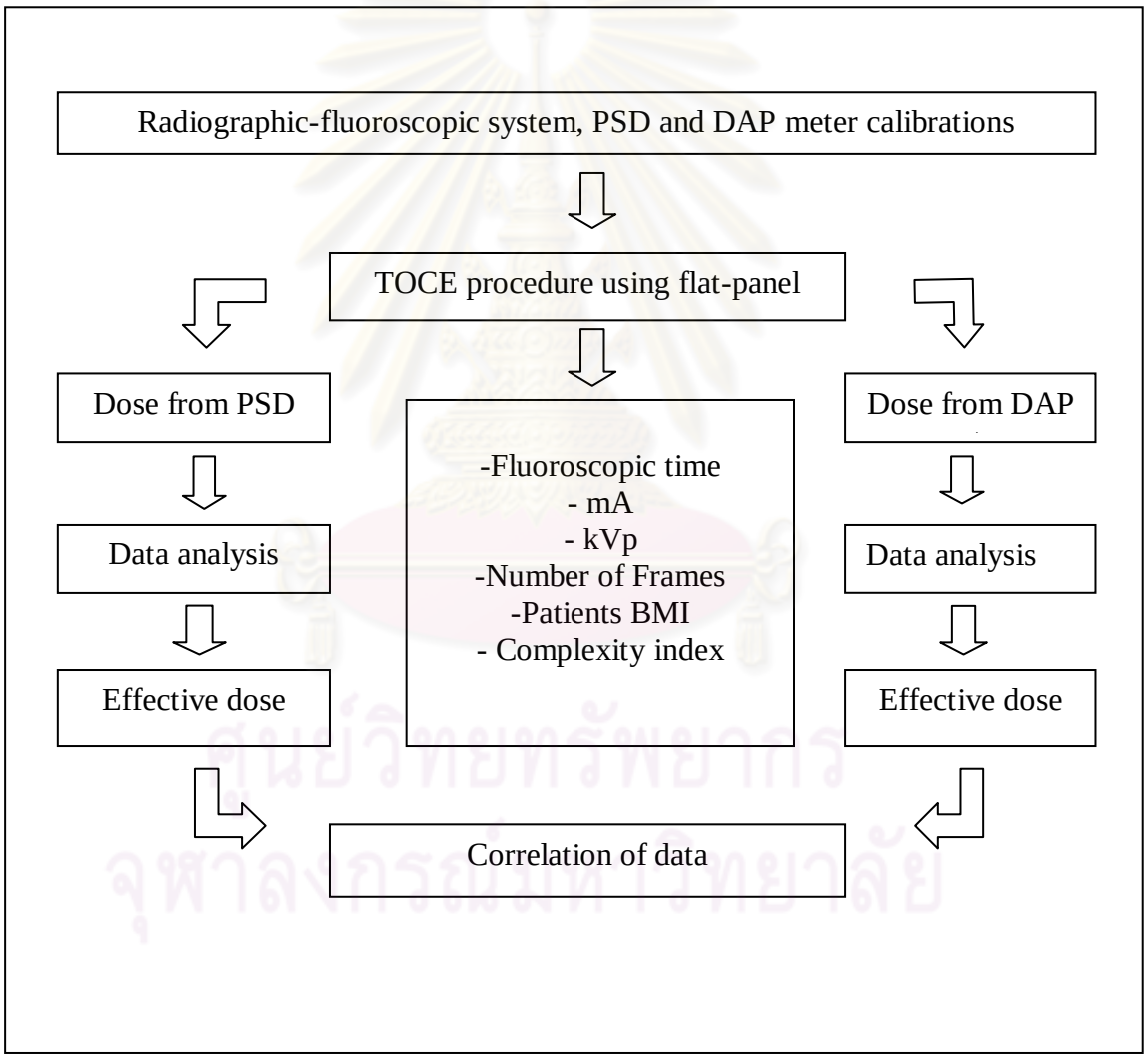


Figure 3.1 Research design model

3.3 Conceptual framework

There are eight parameters influencing the patient effective dose from Angiographic fluoroscopic system with digital flat-panel detector. The factor affecting of patient dose are kVp, mA, fluoroscopic time, number of frames, patient body mass index (BMI), number of procedure, experience of the interventional radiologist and complexity index. The conceptual framework of this study is shown in figure 3.2.

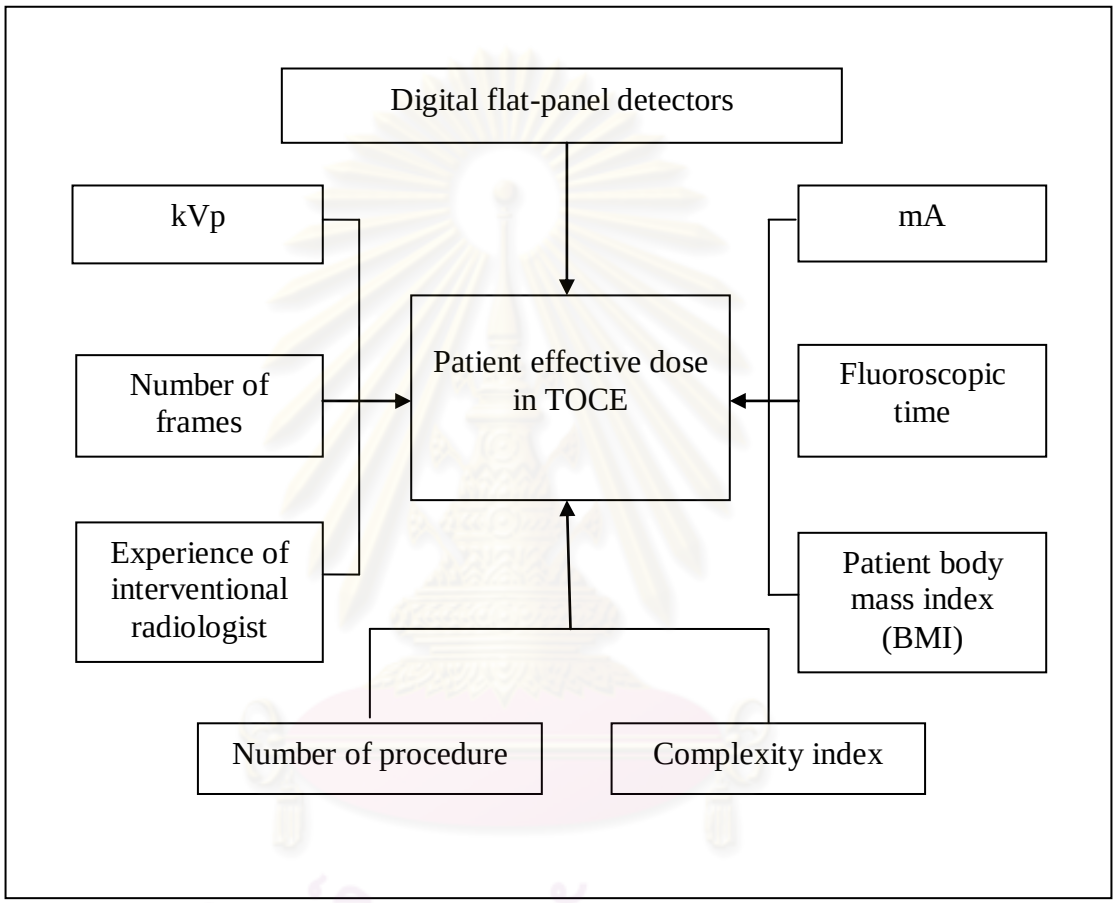


Figure 3.2 Conceptual framework

3.4 Research question

3.4.1 Primary research question:

What is the patient effective dose during TOCE for HCC using the new digital flat-panel system?

3.4.2 Secondary research question:

What is the relationship between effective doses determined by PSD Unfors and the dose area product (DAP) methods?

3.5 Key words

- Patient effective dose
- TOCE Procedure
- Dose area product meter (DAP)
- Patient skin dose meter PSD

3.6 The sample

3.6.1. Target population: The 69 patients who underwent TOCE procedure at King Chulalongkorn Memorial Hospital on Monday to Friday from period of July to November 2009.

3.6.2. Sample population: The 69 patients who underwent TOCE procedure at King Chulalongkorn Memorial Hospital on Monday to Friday from period of July to November 2009, and met the eligible criteria.

3.6.3. Eligible criteria:

3.6.3.1. Inclusion criteria: The Hepatocellular carcinoma or HCC patients who underwent TOCE for both diagnostic and therapeutic procedures using digital Flat-panel system at Vascular and Interventional radiology unit, King Chulalongkorn Memorial Hospital.

3.6.3.2. Exclusion criteria: Unconscious patients.

3.6.4 Sample size determination

Sample sizes for this study is calculated from continuous data estimating the population mean based on the formula and construct 95 % confidence interval(CI) for mean of the population.

$$n = \frac{Z^2_{\alpha/2}\sigma^2}{d^2} \qquad [3.1]$$

$$n = \frac{(1.96)^2.(127)^2}{30^2}$$

$$n = 68.8457$$

α is 0.05
$Z_{\alpha/2}$ is 1.96 (two tails)
σ^2 is variance of data = 127 [1]
d is value of variable data =30 [1]

The sample size (n) for 95% confidence interval is 69 patients.

3.7 Materials

3.7.1. Radiographic-fluoroscopic system

The Digital flat-panel radiographic fluoroscopic system as shown in figure 3.3 is manufactured by Philips, Model Allura Xper FD 20 and installed at Vascular and Interventional Radiology unit, King Chulalongkorn Memorial Hospital in 2008 used for TOCE procedures.

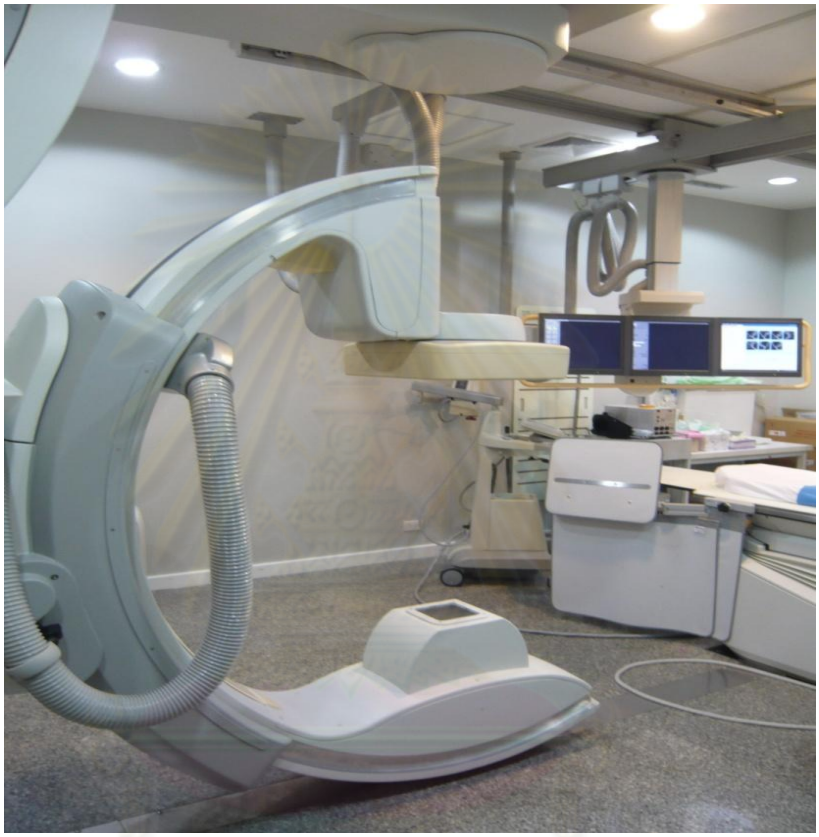


Figure 3.3 Digital RF systems with Flat-panel Detector

The Allura Xper FD 20 unit has a monoplane system for diagnostic and interventional Cardio and Vascular procedure with a ceiling suspended C-arm stand and digital imaging, under couch tube and an over couch digital flat-panel detector the specification as following:

3.7.1.1 X-ray generator and X-ray tube

The Voltage range: 40 kVp to 125 kVp, Max current: 125 mA at 100 kV and anode heat storage capacity: 24 MHU.

3.7.1.2 Automatic wedge filter

Automatic wedge filter: one or two semi-transparent wedge- shaped filters, automatically or manually adjust to the projection.

3.7.1.3 Image chain

Flat detector size 30×40 cm (12×16 inch): six modes subsystem:

- 8 input fields with the field of view sizes are:
  - 48 cm (19 inch)
  - 42 cm (17 inch)
  - 37 cm (15 inch)
  - 31 cm (12 inch)
  - 27 cm (11 inch)
  - 22 cm (9 inch)
  - 19 cm (7.5 inch)
  - 15 cm (6 inch)

- Pixel size : 154×154 µm
- Detective Quantum Efficiency (DQE) :> 73% at low spatial frequencies.
- Output digital video: 2078×2048, 14 bit
- Acquisition speed: 0.5 to 6 frames per second standard and 15 to 30 frames per second optional.
- Fluoroscopy speed: 3.75, 7.5, 15 and 30 frames per second at 1024×1024.

3.7.1.4 Filtration

The minimum inherent filtration (at 75 kVp) of the x-ray tube/collimators is 2.5 mmAl. Besides a wedge filter of 1 mm brass (CuZn 37 r -019;22 mmAl equivalent at 75 kv), an additional filter can be set depending on beam limiting device(BLD) that has the following values:

Table 3.1 Number of filter used in Allura X-per FD 20

No	Filter	Filtration in mm Al-eq (at 75 kVp)
1	0.1 mm Cu+1.0 mmAl	4.0
2	0.4 mm Cu+1.0 mmAl	11.0
3	0.9 mm Cu+1.0 mmAl	21.5

With Allura Xper FD 20 unit, the high beam filter used was 0.1 mm Cu+1.0 mmAl, 0.4 mm Cu+1.0 mmAl, or 0.9 mm Cu+1.0 mmAl and was automatically selected by the system. The system comprises a DAP meter. Air kerma and the following parameters present on the operator console

- Cumulative fluoroscopic time
- Cumulative Dose area product (DAP)
- Cumulated Air kerma (AK)
- Total number of frames
- Total fluoroscopy time
- kV, mAs

The DAP meter was also calibrated according to the same protocol **[17].** The unit has cine digital imaging with CD archiving and it is connected to the PACS workstation

Table 3.2 Technical characteristics of the flat-panel digital X-ray systems at Chulalongkorn Memorial Hospital

Technical characteristic	Philips Allura FD 20
Field of view (cm)	48 ,42, 37, 31, 27, 22, 19, 15
HVL* (mmAl)	6.2
Last image hold	Yes
Fluoroscopy modes	Low, Normal, High
Digital subtraction angiography modes	Low, Normal, High
Image matrix format	1024X1024
Image storage	Monitors, PACS** workstation
The Voltage range(kVp)	40 - 125
Max current (mA)	125 at 100 kV
Flat detector size (cm)	30×40

*HVL is half value layer; **PACS is picture archiving and communications system.

3.7.2. Patient skin dosemeter (PSD)

Patient Skin Dosemeter (PSD) as show in figure 3.4 is manufactured by Unfors, model Unfors PSD Serial No. 144174. Unfors PSD is a solid state detector and used to measure patient entrance skin dose in real time during fluoroscopy procedures. The Unfors PSD can measure on both continuous or pulsed fluoroscopy and exposures with different waveforms. The Unfors PSD consists of several small sensors on cables connected to a display unit. The dimension of small three detectors sensors (H x W x L) are 98 x 82 x 21 mm .In this study PSD Unfors were be placed on the skin of patients and display unit. When the sensor and display unit have been positioned and the instrument turned on, dose is accumulated and alarms (audible and visual) are triggered when selected dose limits are exceeded. The Unfors PSD can be delivered with one, two, three sensors depending on the application. There are four different factory alarm levels set to 25, 50, 75 and 100 % of 2 Gy which is the documented deterministic biological injury level. Accumulated dose can be read in the display units are gray (Gy) or sieverrt (Sv).

Figure 3.4 A solid state detector systems with 3 detectors (www.unfors.com)

3.7.3 Radiation dose meter system

The Radiation dose meter system as show in figure 3.5 is manufactured by Unfors, model XI. Unfors XI was used to calibrate the radiography - fluoroscopic system for kVp, dose, dose rate, HVL, pulse, pulse rate, dose/frame, mA, mAs, time and waveforms. These measured values of kVp and dose are automatically corrected, utilizing Active Compensation, to provide with an accurate and corrected value.

Unfors model XI is a solid state detector were be used for the determination of the table attenuation coefficient, the beam quality half value layer (HVL) and the equipment quality control.

Figure 3.5 The solid state detector systems with ionization chamber for QC (www.unfors.com)

3.7.4 Dose area product meter (DAP)

DAP meter is used to measure the absorbed dose in air (cGy), times the area of the x-ray field (cm^2), on patient skin. The relationship between DAP and exposure-area-product (EAP) is essentially a single conversion factor that relates dose to expressed in roentgen cm(R-cm^2) and DAP is expressed in gray-cm^2.DAP is usually read in mGy.cm^2.In this study the DAP meter is a part of the Allura Xper FD 20 unit as shown in figure 3.6, The total amount of exposure determines the absorbed dose in the irradiated volume of the patient's body.

The absorbed dose depends on the radiation exposure and the irradiation area. Therefore, the estimation of the patient's absorbed dose from the dose area product is easily made than from the factors. The DAP meter of Allura Xper FD 20 unit measure the dose-area product in the unit Gycm^2 of the quantity air kerma times during radiography and fluoroscopy.

For recording the dose-area product the Allura Xper FD 20 system comprises a DAP meter and fixed to the light beam diaphragm of the x-ray tube. The presented on the operator console, the display units are mGycm^2.

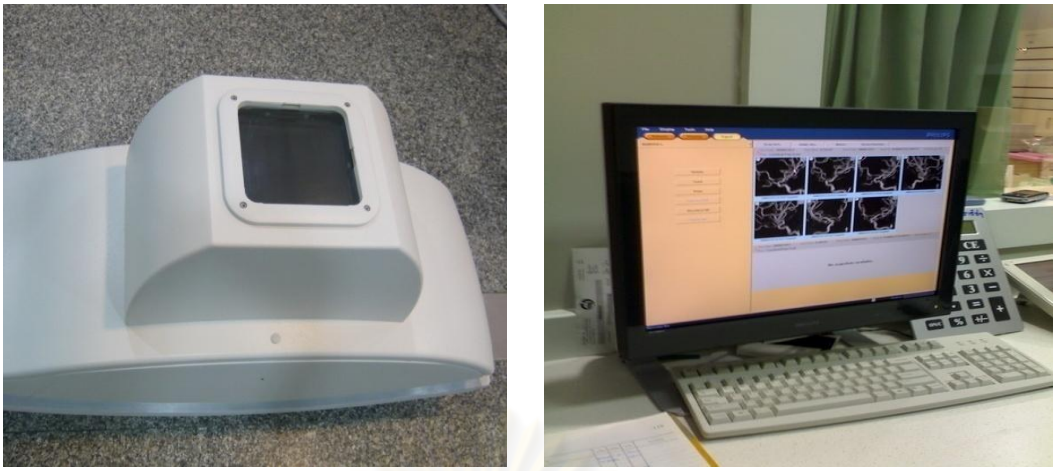


Figure 3.6 DAP meter of Allura Xper FD 20 unit and operator console for readout value.

3.7.5 Portal film (Verification film) Kodak X-Omat V

The non screen ready packed film was used for the radiation area verification.

3.7.6 The patients

Sixty-nine patients who underwent TOCE procedure were examined by the digital Flat-panel system at Vascular and Interventional Radiology unit, King Chulalongkorn Memorial Hospital.

3.7.7 Data recording, complexity index and case consent forms (Appendix)

The patient consent form (appendix I) were accessed before procedure and record the patient data in data recording (appendix II). The complexity indexes (appendix III) of procedures were accessed by interventional radiologist at the end of the procedure.

3.8 Methods

This study is carrying out into eight steps.

3.8.1. Perform QC in Digital Flat-panel Radiographic –Fluoroscopic system

- Dose assessment
- Automatic brightness control test
- Maximum dose rate assessment
- Table attenuation
- Image size assessment
- Half value layer (HVL)
- Image quality assessment

The results should fall within the limits recommended by IAEA

3.8.2 Calibrate Unfors PSD and DAP meter with solid state detectors.

In this study we calibrated the Unfors PSD, DAP meter with solid state detector as shown in figure 3.7 to obtain calibration factors.

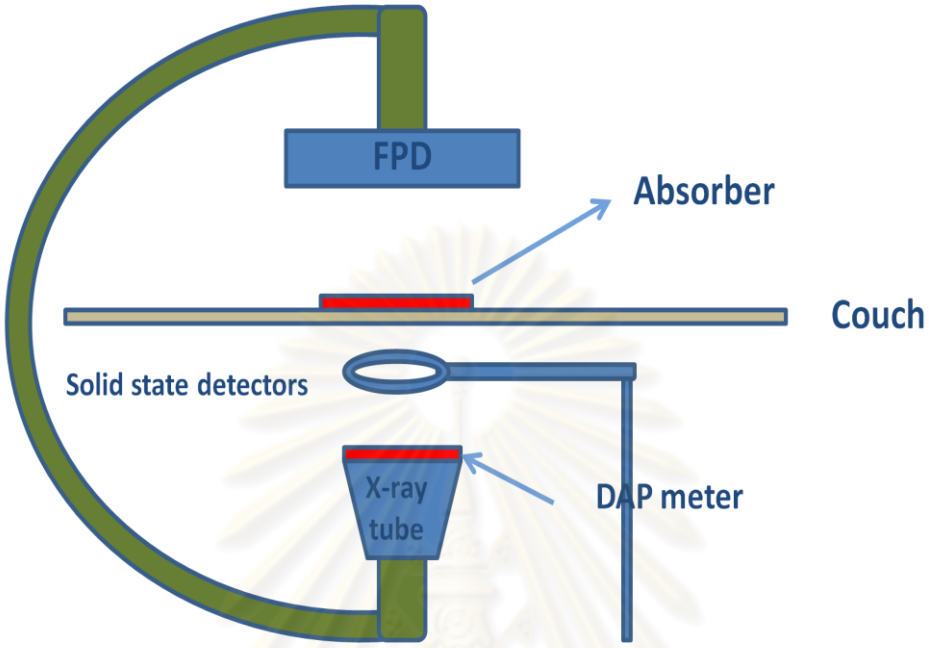


Figure 3.7 DAP and solid state detectors setup to obtain the DAP calibration factor

3.8.3. The patient consent form (see Appendix I-II).

3.8.4. Record the patient data

Such as patient's weight, height, age, gender, kVp, mA, fluoroscopic time and number of frames in the case record form.

3.8.5. Dosimetric procedure.

3.8.5.1 Place PSD on patient's back at three points of liver (left, middle, right) to fallowing while patient expiration as show in figure 3.8.

- Left lobe : place PSD on the T-12
- Middle lobe : place PSD 2 inch away from left lobe to the right side of patient.
- Right lobe : place PSD 2 inch away from middle lobe with 30° downward

However, fluoroscopic guide must be performed to confirm the PSD position.

3.8.5.2 Place verification film on the couch at fluoroscopic region.

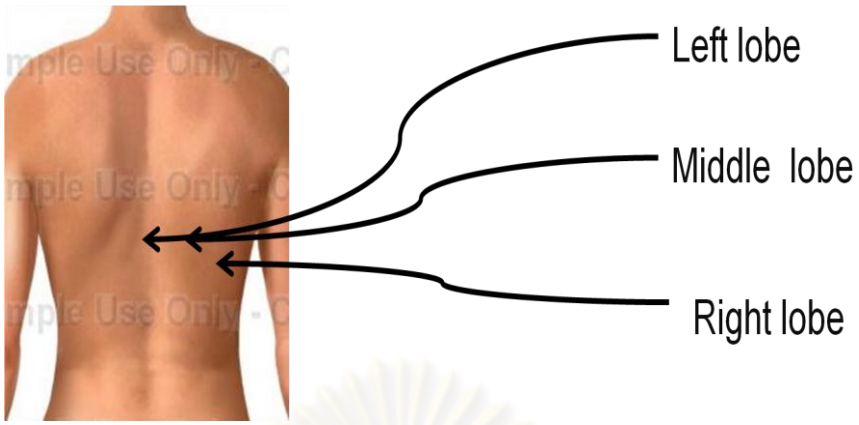


Figure 3.8 Position of PSD with placed on patients back at three point of liver.

3.8.6 Record patient dose using Unfors PSD and DAP meter in the case record form.

3.8.7 Peak and average skin doses

- The peak skin dose was collected by Patient Skin Dosemeter (PSD Unfors) from three detectors and calculate peak skin dose (3.10.1).
- The average skin dose was collected by Dose area product meter (DAP) and calculate average skin dose (3.10.2)

3.8.8. Evaluate and correlate of the effective dose from both methods

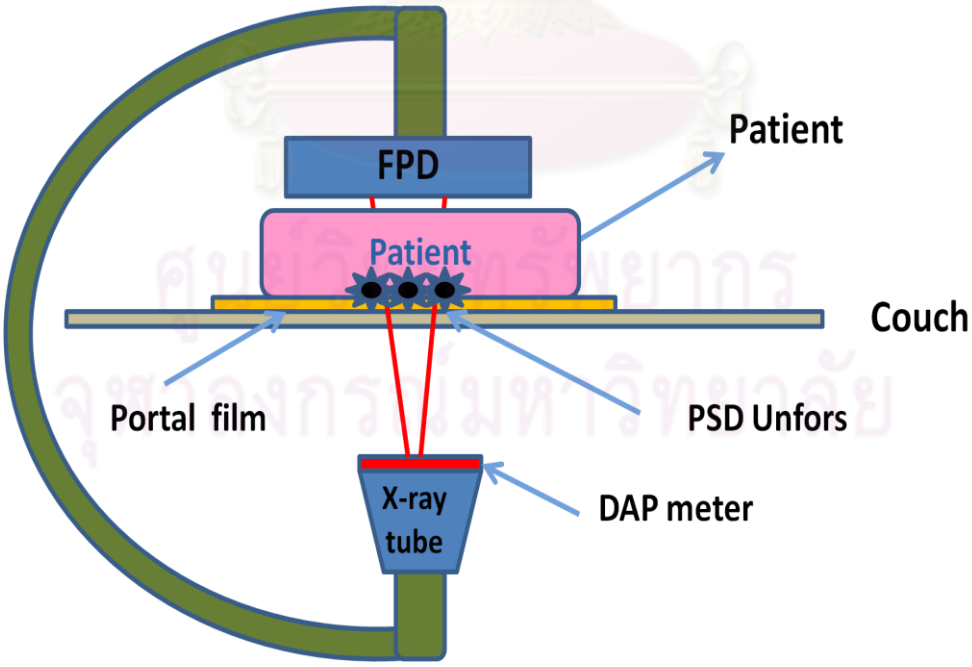
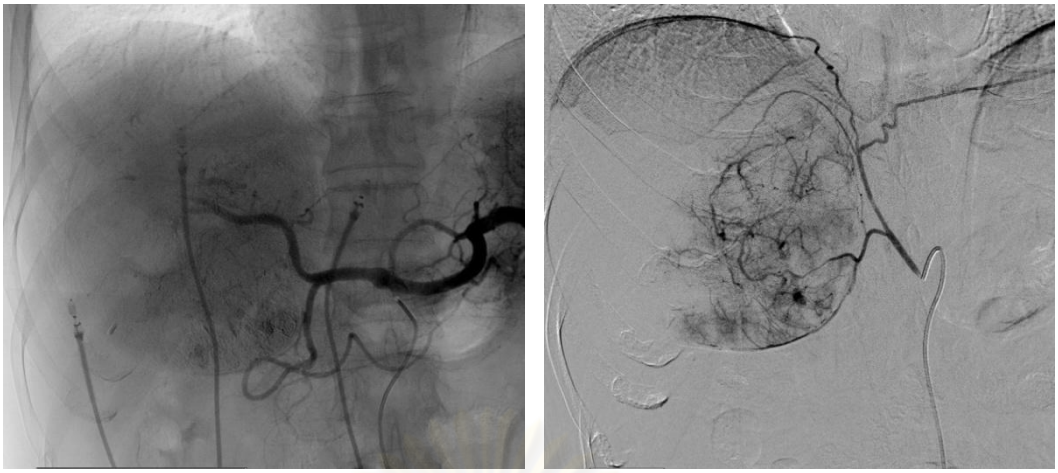


Figure 3.9 Setting of the devices for patient skin dose determination.



(a) (b)

Figure 3.10 Place PSD on patient's back at three regions over liver area (a). After subtraction PSD is not interfering in TOCE images (b).

3.9 Data collection

3.9.1 The patient consent form was accessed before procedure.

3.9.2 During the TOCE procedure patient's data are recorded in case record form as following

- Facility identification
- Date
- Patient weight
- Patient height
- Patient age
- Gender
- kVp, mA, SID, FOV
- Fluoroscopic time
- Number of frames
- Number of procedure
- etc

3.9.3 The peak skin dose was recorded from Patient Skin Dosimeter (PSD Unfors) from three detectors recorded from case record form.

3.9.4 The average skin dose was recorded from Dose area product meter (DAP) in case record form.

3.9.5 The complexity indexes of procedures were reported by interventional radiologist for the difficulty of procedure after ended procedure.

3.10 **Data analysis**

3.10.1 Peak skin dose (maximum entrance surface dose)

The peak skin dose calculation is calculated from equation [3.2]

$$\text{ESD (mGy)} = \text{dose from PSD} \times \text{Calibration factor of PSD} \quad [3.2]$$

ESD is Entrance surface dose (mGy)

Calibration factors from PSD (appendix II)

3.10.2 Average skin dose (average entrance surface dose)

The average skin dose is calculated from equation [3.3]

$$\text{ESD(mGy)} = \frac{\text{Patient dose from DAP (mGycm}^2\text{)}}{\text{Exposed area (cm}^2\text{)}} \times \text{BSF} \times \text{table attenuation factor} \quad [3.3]$$

ESD is Entrance surface dose (mGy)

BSF is back scatter factor

Table attenuation factor is measured during QC procedure

Exposed area is measured from portal film

3.10.3 Effective dose (ED)

The effective dose, E, is defined in ICRP 60 **[5]** and ICRU 51**[11].** It is the sum over all the organs and tissues of the body of the product of the equivalent dose, H_T, to the organ or tissue and a tissue weighting factor, W_T, for that organ or tissue, thus:

$$ED = \sum_T W_T H_T \quad [3.4]$$

The tissue weighting factor, W_T, for organ or tissue T represents the relative contribution of that organ or tissue to the total detriment arising from stochastic effects for uniform irradiation of the whole body. W_T is shown in Table 2.2

Unit: J/kg. The special name for the unit of effective dose is sievert (Sv). The sum over all the organs and tissues of the body of the tissue weighting factors, W_T, is unity.

3.11 Statistical analysis

This study is Descriptive statistics for continuous data to determine as following

- Range (minimum-maximum)
- Average
- Median
- Standard deviations (SD)
- 95% confidence interval (CI)

This determination was analyzed using SPSS for windows evaluation version.

3.11.1 Outcome

The Patient effective dose in TOCE procedure

3.11.2 Outcome measurement

This study involves the correlation of the data from independent variables and dependent variable. The measurement of this study consist of 2 types of variables

- Dependent variable: Patient Effective dose.
- Independent variables: fluoroscopic time, kVp, mA, patient size (BMI), number of frames, complexity index.

Correlate relationship between effective doses determined by PSD Unfors and the dose area product (DAP) methods.

3.12 Data presentation

The table, bar chart and scatter diagram are presented.

3.13 Limitations

3.13.1 DAP measurement is the accumulation of the dose area product which integrate all irradiated skin dose at target and non-target organs. The average skin dose will be obtained would be inaccurate. Unfors PSD measured dose at a point at target organ and the peak dose could be obtained.

3.13.2 The accuracy of the skin exposed area, because the FOV and the tube angulations were variable during TOCE procedure.

3.14 Ethical considerations

The data was collected after the approval of the Ethics Committee of Faculty of Medicine, Chulalongkorn University. The ethical principle in research involving human subjects was considered: and approved in May 2009.

3.14.1 Respect for persons

- Respect for free and informed consent: the patient who participates in this research can decide after obtain the information; can withdraw from this research at any time.

- Respect for confidential: the patient data was used for academic objective only, conceal to the public and no patient's name reveal according to the law.

3.14.2 Beneficence or non-maleficence

- The patient who participates in this research was informed the effective dose from TOCE procedure after the complete of the research.

- The result from this research was the reference data for other patient in the future.

- The small dosemeter was taped by the researcher on patient skin at three position according the liver

3.14.3 Justice

- Selection of subjects for this research has obviously inclusion and exclusion criteria, non bias.

3.15. Expected benefits

3.15.1. Optimization of patient skin dose in TOCE interventional radiology, the patient effective dose is very important for interventional radiologists to optimize the patient dose using the correlation between patient effective doses and affecting factors.

3.15.2. Reduction of the Staff dose during TOCE procedure using digital flat-panel system.

CHAPTER IV

RESULTS

4.1 The equipment calibration.

The Radiographic/Fluoroscopic system was calibrated for the following topics.

- Dose assessment
- Automatic brightness control test
- Maximum dose rate assessment
- Table attenuation
- Image size assessment
- Half value layer (HVL)
- Image quality assessment

The results of equipment calibration values are shown in APPENDIX D.

4.2 Table attenuation determination.

The percentage of table attenuation which is directly affecting the average patient skin dose is shown in Table 4.1. The correction factor was applied to the readout from DAP meter in all data collection.

Table 4.1 The results of table attenuation determined by Unfors XI. (solid state detector)

Mode	Sub mode/Image Quality	Dose rate (mGy/min)	Table attenuation %	Absorber
C-arm at 0°	Normal	49.3	5.9	2 mmCu
C-arm at 90°	Normal	52.4		

** Measurement of dose rate in fluoroscopy for the same mode and field size.

4.3 The patient studies.

Our study included sixty-nine consecutive patients (15 women and 54 men) who underwent TOCE procedures during the period July to November 2009 as shown in table 4.2. The mean age was 59.64±10.58 years (range, 36-82 years),the patient height and weight were 164.13± 9.28 cm (range, 145-182 cm) and 62.46 ± 13.85 kg (range, 37-120 kg), the BMI and patient thickness were 23.13± 4.35 kg/m^2 (range 13.7-37.87 kg/m^2) and 21.88± 2.13 cm(17.38-29.31 cm) respectively. Those are summarized Table 4.3. All patients gave informed consent.

Table 4.2 The patient data underwent TOCE procedure from 69 patients.

No of procedure	Sex (M/F)	Age (Years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Thickness (cm)
1	M	67	169	74	25.91	23.62
2	M	63	170	70	24.22	22.90
3	F	54	151	66	28.95	23.60
4	M	79	166	72	26.13	23.51
5	M	53	156	43	17.67	18.74
6	M	49	168	68	24.09	22.71
7	M	55	160	43	16.80	18.50
8	M	53	168	69	24.45	22.87
9	M	60	160	75	29.30	24.44
10	M	40	168	78	27.64	24.32
11	M	68	152	49	21.21	20.26
12	M	47	153	69	29.48	23.97
13	M	68	165	46.3	17.01	18.91
14	M	59	170	67	23.18	22.41
15	M	58	170	56	19.38	20.48
16	F	63	153.5	81.2	34.46	25.96
17	M	54	180	92	28.40	25.52
18	M	56	182	70	21.13	22.13
19	M	53	167	65	23.31	22.27
20	F	62	150	61	27.11	22.76
21	M	70	156	37	15.20	17.38
22	M	49	173	41	13.70	17.38
23	M	68	173	87	29.07	25.31
24	M	59	165	74	27.18	23.90
25	M	65	162	61.6	23.47	22.01
26	M	51	165	65	23.88	22.40
27	F	59	152	58	25.10	22.05
28	F	66	163	59.9	22.55	21.64
29	M	54	170	65	22.49	22.07
30	M	78	170	61	21.11	21.38
31	M	53	180	79	24.38	23.65
32	F	72	145	57	27.11	22.38
33	M	52	156	53	21.78	20.80
34	M	52	165	44.5	16.35	18.54
35	M	54	168	73	25.86	23.53
36	F	66	150	51	22.67	20.81
37	M	78	170	53	18.34	19.93
38	F	66	158	70	28.04	23.76
39	M	70	174	70	23.12	22.64
40	M	65	175	72	23.51	22.89

Table 4.2 The patient data underwent TOCE procedure from 69 patients. (Continue)

Number of procedure	Sex (M/F)	Age (Years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Thickness (cm)
41	M	61	175	78.2	25.53	23.86
42	M	55	178	78	24.62	23.63
43	M	52	156	52	21.37	20.61
44	M	46	170	58	20.07	20.85
45	M	70	169	59	20.66	21.09
46	M	63	172	74	25.01	23.41
47	M	62	178	83	26.20	24.37
48	M	58	150	40	17.78	18.43
49	F	59	153	54	23.07	21.20
50	M	45	162	63	24.01	22.26
51	M	47	164	59.2	22.01	21.44
52	M	54	165	62	22.77	21.88
53	M	38	167	55	19.72	20.48
54	F	76	145	45	21.40	19.88
55	F	56	167	64	22.95	22.10
56	M	61	177	64	20.43	21.46
57	M	55	169	52	18.21	19.80
58	M	78	158	55	22.03	21.06
59	M	46	170	56.7	19.62	20.61
60	M	76	164	61	22.68	21.77
61	F	71	145	57	27.11	22.38
62	M	56	167.5	48	17.11	19.11
63	M	82	170	52	17.99	19.74
64	F	79	165	56	20.57	20.79
65	F	59	150	65	28.89	23.50
66	M	57	160	53.2	20.78	20.58
67	M	40	178	120	37.87	29.31
68	F	36	156	43	17.6	18.7
69	M	69	156	56	23.01	21.38
Average	M=54	59.64	164.13	62.46	23.13	21.88
Min	F=15	36.00	145.00	37.00	13.70	17.38
Max	-	82.00	182.00	120.00	37.87	29.31
SD	-	10.58	9.28	13.85	4.35	2.13

Table 4.3 The patient data underwent TOCE procedure.

patient data	Mean ± SD	Range
Age (Years)	59.64±10.58	36-82
Height(cm)	164.13± 9.28	145-182
Weight(kg)	62.46 ± 13.85	37-120
BMI (kg/m^2)	23.13± 4.35	13.7-37.87
Thickness(cm)	21.88± 2.13	17.38-29.31

4.4 Average values of the technical parameters.

Average values of the technical parameters used to perform the fluoroscopy part and corresponding values for the radiography part of the TOCE procedure are given in table 4.4

Table4.4 Average values of the technical parameters.

TOCE Procedure	Fluoroscopy		Radiography (DSA)	
	Average(SD)	range	Average(SD)	Range
kVp	97±13	75-120	80±0.34	80-81
mA	-	-	23±14	11-53
FOV (cm)	31±12	15-48	31±12	8-66
Frame rate(f/s)	NA	NA	3f/s	1-3
No of frames (frames)	NA	NA	200.19±176	75-1413
Filter	0.00 mmAl	-	0.01 mmAl	-
Mode	normal	-	normal	-

4.5 Procedures performed with a Flat-panel system (Philip Allura FD 20)

The Procedures Performed with a Flat-panel System (Philip Allura FD 20) in TOCE procedure such as fluoroscopic time, number of frames, number of procedures and frame rate. Those factors are shown in table 4.5

The average fluoroscopic time was 16.06± 11.26 min with the range of 3.38-59.13 min average number of frame was 200.19±176.77 frames, and the range was 75-1413 frames, number of procedure was 2.24 ± 1.28 time range 1-6 times. The procedures were performed by seven experienced radiologists using standard techniques. Every case was attended by a physician training. The average experience of interventional radiologist from 69 cases was 3.8±4.1 years; range was 1-23 years.
From the all sample that has been taken, only one case that was diagnostic type of procedure. (Table 4.6)

Table 4.5 The procedures performed with a Digital Flat-Panel System (Philips Allura x-per 20) in TOCE procedure**.**

Procedure No.	Total Fluoroscopic Time (min)	Total Number of Frames		Number of procedure (time)	Frame rate (f/s)	Experience of radiologist (years)
		DSA	x-per CT			
1	26.18	230	0	1	3f/s	3
2	3.55	75	0	*	3f/s	3
3	39.12	189	0	5	2f/s	3
4	15.56	282	0	5	3f/s	15
5	11.18	104	0	2	3f/s	3
6	9.52	136	0	1	3f/s	3
7	14.19	177	0	2	3f/s	3
8	17.54	441	0	3	2f/s	23
9	15.05	303	0	3	3f/s	3
10	4.04	86	0	*	3f/s	1
11	28.14	86	0	2	3f/s	3
12	13.52	164	0	1	3f/s	3
13	27.34	137	0	3	3f/s	3
14	7.59	148	0	3	3f/s	3
15	18.38	196	0	6	3f/s	3
16	11.24	121	0	2	3f/s	3
17	8.35	129	0	3	3f/s	3
18	24	213	0	*	3f/s	15
19	23.2	214	0	4	3f/s	3
20	59.13	154	224	4	3f/s	3
21	7.09	81	0	2	3f/s	3
22	7.43	111	0	1	3f/s	3
23	6.42	93	0	3	3f/s	3
24	16.06	87	0	2	3f/s	3
25	27.09	300	1114	2	3f/s	3
26	17.48	202	0	3	3f/s	3
27	10.52	224	0	1	3f/s	3
28	20.28	207	0	1	3f/s	3
29	13.47	119	0	1	3f/s	3
30	16.29	214	0	2	3f/s	3
31	5.06	137	0	1	3f/s	3
32	15.23	192	0	2	3f/s	3
33	14.08	87	0	3	3f/s	3
34	15.23	161	0	1	3f/s	3
35	10.21	208	0	1	3f/s	3
36	4.45	121	0	2	3f/s	3
37	12.17	166	0	3	3f/s	3

Table 4.5 The procedures performed with a Digital Flat-Panel System (Philips Allura x-per 20) in TOCE procedure**.** (Continue)

Procedure No.	Total Fluoroscopic Time (min)	Total Number of Frames		Number of procedure	Frame rate	Experience of radiologist
		DSA	x-per CT			
38	9.51	131	0	2	3f/s	3
39	8.19	103	0	1	3f/s	3
40	9.14	149	0	2	3f/s	1
41	17.4	170	0	3	3f/s	3
42	10.27	205	0	2	3f/s	15
43	8.27	259	0	4	3f/s	3
44	4.52	119	0	1	3f/s	3
45	3.56	75	0	3	3f/s	3
46	5.54	117	0	1	3f/s	1
47	6.44	123	0	1	3f/s	1
48	10.22	148	0	4	3f/s	3
49	13.15	198	0	2	3f/s	1
50	15.56	139	0	3	3f/s	1
51	16.44	127	0	1	3f/s	1
52	17.21	264	0	3	3f/s	3
53	23.22	294	0	1	3f/s	3
54	52.55	301	0	5	3f/s	3
55	17.09	248	0	3	3f/s	3
56	3.38	96	0	1	3f/s	3
57	7.26	118	0	1	3f/s	3
58	18.16	185	0	1	3f/s	15
59	11.48	106	0	2	3f/s	3
60	14.53	166	0	1	3f/s	1
61	16.03	228	0	1	3f/s	1
62	29.5	404	0	4	3f/s	3
63	12.27	97	0	1	3f/s	1
64	20.59	361	0	1	3f/s	3
65	27.58	170	0	2	3f/s	1
66	55.49	618	0	1	3f/s	3
67	7.1	119	0	2	3f/s	3
68	22.43	230	0	2	3f/s	15
69	19.01	113	0	5	3f/s	1
Average	16.06	200.19	19.39	2.24	3f/s=68	3.81
Min	3.38	75.00	0.00	1.00	2f/s=1	1
Max	59.13	1413.0	1114.0	6.00	-	23
SD	11.26	176.77	136.40	1.28	-	4.06

*number of procedure mean number of patients repeated the procedure

Table 4.6 The factors affecting patient ESD in TOCE procedure

Factors affecting of ESD	Mean ± SD	Range
Fluoroscopic time (min)	16.06± 11.26	3.38-59.13
Number of frames(DSA)	200.19±176.77	75-1413
Number of procedures	2.24±1.28	1-6
Experience of radiologist (years)	3.8±4.1	1-23

4.6 The entrance surface dose (ESD) and effective dose (ED) determined by DAP method in TOCE procedures. (Table 4.7)

4. 6.1 The average entrance surface dose (average ESD).

The average entrance surface dose (ESD) from DAP meter readout ($Gycm^2$) was 222.60 ± 114.62 $Gycm^2$ and the range was 22.58-537.43 $Gycm^2$. The 3rd Quartile was 294.43 $Gycm^2$**.**

The average entrance surface dose (ESD) measurement from dose area product (DAP) meter with verification area film included the backscatter factors was 968.66±527.08 mGy, the range was 111.28-2365.74 mGy. The 3rd Quartile was 1263.9 mGy.

4.6.2 The average effective dose (ED).

The effective doses, ED were evaluated by the equation:

$$ED = \sum_T W_T H_T$$

Where, W_T is the tissue weighting factor (ICRP 103)

$$H_T = D_T . W_R$$

Where D_T : Organ dose = 0.01 (ICRP 103),
W_R : Radiation weighting factor = 1 for x-ray

The average effective dose (ED) was 9.7 ± 5.27 mSv and the range was 1.11-23.66 mSv. The 3rd Quartile was 17.69 mSv.

The average ESD and average ED were shown in table 4.9

Table 4.7 The entrance surface dose (ESD) and effective dose (ED) determined by DAP method in TOCE procedure.

Case number	DAP meter readout values ($Gycm^2$)	Corrected DAP* ($Gycm^2$)	ESD** (mGy)	ED (mSv)
		DAP ($Gycm^2$) × BSF × TF (%)	DAP ($mGycm^2$)/E_A (cm^2) × BSF × TF (%)	
1	247.37	321.23	803.08	8.03
2	73.24	95.10	205.85	2.06
3	296.47	384.99	874.98	8.75
4	296.28	384.75	961.87	9.62
5	40.73	52.89	172.84	1.73
6	188.94	245.35	613.38	6.13
7	110.94	144.06	389.36	3.89
8	367.20	476.84	1149.01	11.49
9	537.43	697.89	2365.74	23.66
10	120.26	156.17	332.28	3.32
11	188.46	244.73	1182.29	11.82
12	223.78	290.60	1068.38	10.68
13	162.95	211.60	717.30	7.17
14	142.08	184.50	663.68	6.64
15	135.97	176.57	573.29	5.73
16	252.21	327.51	889.98	8.90
17	231.63	300.79	919.85	9.20
18	215.59	279.96	1171.40	11.71
19	220.02	285.72	936.77	9.37
20	388.37	504.32	2017.30	20.17
21	32.58	42.31	171.99	1.72
22	32.56	42.29	111.28	1.11
23	196.75	255.49	594.16	5.94
24	229.53	298.06	726.97	7.27
25	458.59	595.52	1815.60	18.16
26	302.09	392.29	1569.16	15.69
27	22.58	29.32	127.47	1.27
28	288.05	374.06	1294.32	12.94
29	245.67	319.02	883.71	8.84
30	294.44	382.35	1323.01	13.23
31	228.21	296.35	1025.42	10.25
32	207.33	269.23	1196.58	11.97
33	117.36	152.39	527.32	5.27
34	223.36	290.05	1160.18	11.60
35	368.84	478.96	1915.85	19.16
36	101.78	132.17	457.33	4.57
37	160.77	208.77	722.37	7.22
38	188.71	245.05	847.93	8.48
39	144.97	188.25	651.38	6.51
40	295.04	383.14	1325.73	13.26

Table 4.7 The entrance surface dose (ESD) and effective dose (ED) determined by DAP method in TOCE procedure. (Continue)

Case number	DAP meter readout values ($Gycm^2$)	Corrected DAP* ($Gycm^2$)	ESD** (mGy)	ED (mSv)
		DAP ($mGycm^2$) × BSF × TF (%)	DAP ($mGycm^2$)/E_A (cm^2) × BSF × TF (%)	
41	393.75	511.32	1769.28	17.69
42	277.90	360.87	1248.69	12.49
43	137.90	179.07	619.62	6.20
44	117.84	153.02	529.49	5.29
45	103.56	134.48	465.33	4.65
46	199.32	258.83	895.59	8.96
47	429.27	557.44	1928.85	19.29
48	75.99	98.67	341.43	3.41
49	304.58	395.52	1368.56	13.69
50	200.61	260.51	901.40	9.01
51	114.79	149.06	515.78	5.16
52	401.04	520.79	1802.02	18.02
53	283.05	367.56	1271.85	12.72
54	281.29	365.27	1263.93	12.64
55	195.74	254.19	879.55	8.80
56	87.94	114.20	395.14	3.95
57	116.20	150.90	522.15	5.22
58	479.89	623.18	2156.33	21.56
59	121.32	157.55	545.14	5.45
60	233.97	303.83	1051.32	10.51
61	201.29	261.39	904.48	9.04
62	238.07	309.15	1069.71	10.70
63	120.16	156.04	539.94	5.40
64	303.78	394.49	1365.00	13.65
65	240.10	311.79	1078.84	10.79
66	303.71	394.40	1364.69	13.65
67	473.50	614.88	2127.62	21.28
68	168.234	218.47	755.94	7.56
69	175.583	228.01	788.96	7.89
Average	222.60	289.07	969.90	9.70
Min	22.58	29.32	111.28	1.11
Max	537.43	697.89	2365.74	23.66
SD	114.62	148.85	527.08	5.27
3rd Quartile	294.436	382.35	1263.9	17.69

*Corrected DAP ($Gycm^2$), determined included back-scatter factor (BSF) and Table attenuation factor (TF),

** Entrance surface dose, ESD (mGy), determined from verification exposure area (E_A) included back-scatter factor (BSF) and Table attenuation factor (TF),

4.7 The entrance surface dose (ESD) and the effective dose (ED) determined by Unfors PSD methods in TOCE procedures. (Table 4.8)

4. 7.1 The peak entrance surface dose (peak ESD)

The average of peak ESD determined by Unfors PSD was 968.66 mGy at left lobe of liver, the range was 175.18-3145.29 mGy, the middle lobe was 848.41mGy, the range was 120.97-2877.66 mGy and the right lobe of liver was 572.14 mGy which the range was 64.49-1631.73 mGy. (Figure 4.1)

The average of peak ESD from three points above the liver was 1004.2±565.11; the range was 192.62-3145.29 mGy. The 3rd Quartile was 1263.9 mGy as in Table 4.8.

4.7.2 The peak effective dose (Peak ED).

The effective doses, ED were evaluated by the equation: 3.4

$$ED = \sum_T W_T H_T$$

Where, W_T is the tissue weighting factor at skin (0.01) (ICRP 103)

H_T is $H_T = D_T.W_R$

Where D_T: Organ dose (skin) = 0.01 (ICRP 103)
W_R: Radiation weighting factor = 1 for x-ray

The average peak ED determined by Unfors PSD was 9.68± 5.50 mSv at left lobe of liver, the range was 1.75-31.45 mSv, the middle lobe was 8.48 mSv, the range was 1.20 -28.77 mSv and the skin dose at right lobe of liver was 5.72 mSv which the range was 6.4-16.31 mSv. (Figure 4.2)

The average of peak ED from three points above the liver was 10.04±5.65 mSv, the range was 1.93-31.45 mSv. The 3rd Quartile was 13.83 mSv.

The summarize of peak ESD and peak ED were shown in table 4.10.

Table 4.8 The entrance surface dose (ESD) and effective dose (ED) determined by Unfors PSD methods in TOCE procedures.

Case no	Entrance surface dose, ESD (mGy)			peak ESD (mGy)	Effective dose , ED (mSv)
	Left portion of liver	Middle portion of liver	Right portion of liver		
1	1817.8	1155.39	1328.2	1817.82	18.18
2	263.15	250.46	197.36	263.15	2.63
3	1382.8	1226.41	427.99	1382.82	13.83
4	262.90	250.26	197.32	262.90	2.63
5	192.62	120.97	95.12	192.62	1.93
6	497.90	669.82	640.68	669.82	6.70
7	506.76	556.61	448.54	556.61	5.57
8	1432.5	881.56	1286.5	1432.52	14.33
9	1340.8	2164.24	1631.7	2164.24	21.64
10	427.04	335.60	156.35	427.04	4.27
11	1322.4	886.39	274.44	1322.47	13.22
12	939.36	907.68	721.75	939.36	9.39
13	872.62	395.59	600.75	872.62	8.73
14	629.74	556.61	496.31	629.74	6.30
15	680.86	533.64	508.39	680.86	6.81
16	1384.1	1281.41	1005.1	1384.17	13.84
17	1285.3	1160.57	788.91	1285.31	12.85
18	1563.4	1117.16	376.37	1563.45	15.63
19	1204.6	1020.78	746.35	1204.62	12.05
20	3145.2	2877.66	1551.1	3145.29	31.45
21	175.22	177.26	200.62	200.62	2.01
22	175.18	177.21	200.58	200.58	2.01
23	767.89	597.21	385.82	767.89	7.68
24	789.50	674.70	495.73	789.50	7.89
25	2132.0	1470.21	1054.4	2132.09	21.32
26	1249.3	1237.02	1077.6	1249.39	12.49
27	968.80	468.02	227.40	968.80	9.69
28	1051.9	650.89	605.36	1051.95	10.52
29	784.96	648.51	593.29	784.96	7.85
30	1365.3	1217.56	924.09	1365.37	13.65
31	921.86	822.52	669.63	921.86	9.22
32	1044.4	625.15	305.99	1044.42	10.44
33	494.02	469.17	414.52	494.02	4.94
34	984.43	821.36	500.33	984.43	9.84
35	1666.4	1488.51	939.60	1666.45	16.66
36	429.51	401.74	308.56	429.51	4.30
37	706.00	720.40	448.06	720.40	7.20
38	1095.9	913.46	506.43	1095.90	10.96
39	502.86	463.02	309.38	502.86	5.03
40	1098.9	1482.84	792.68	1482.84	14.83

Table 4.8 The entrance surface dose (ESD) and effective dose (ED) determined by Unfors PSD methods in TOCE procedures. (Continue)

Case no	Entrance surface dose, ESD (mGy)			Maximal ESD* (mGy)	Effective dose ED (mSv)
	Left portion of liver	Middle portion of liver	Right portion of liver		
41	1695.13	1809.26	1073.48	1809.26	18.09
42	1089.74	853.94	305.02	1089.74	10.90
43	532.17	466.77	229.84	532.17	5.32
44	376.85	330.51	223.91	376.85	3.77
45	438.47	326.59	64.49	438.47	4.38
46	536.42	783.34	480.76	783.34	7.83
47	1351.36	1255.04	940.71	1351.36	13.51
48	456.50	444.78	211.70	456.50	4.56
49	1300.78	1193.45	623.68	1300.78	13.01
50	588.71	1095.51	903.46	1095.51	10.96
51	439.30	421.99	334.61	439.30	4.39
52	1390.50	1331.36	1034.24	1390.50	13.91
53	1358.57	1330.30	964.45	1358.57	13.59
54	1650.06	1256.10	399.25	1650.06	16.50
55	1289.56	875.77	550.25	1289.56	12.90
56	270.07	135.15	192.30	270.07	2.70
57	415.71	425.70	337.14	425.70	4.26
58	1567.66	1246.56	688.52	1567.66	15.68
59	406.23	359.02	194.12	406.23	4.06
60	885.80	529.15	403.70	885.80	8.86
61	453.20	201.08	231.29	453.20	4.53
62	1175.23	1072.72	807.19	1175.23	11.75
63	428.48	327.54	229.67	428.48	4.28
64	1342.09	1393.90	506.92	1393.90	13.94
65	1464.66	1310.16	512.88	1464.66	14.65
66	1773.66	1613.32	1200.89	1773.66	17.74
67	1427.58	1106.64	500.25	1427.58	14.28
68	586.07	614.59	502.68	614.59	6.15
69	589.98	554.49	390.37	589.98	5.90
Average	968.66	848.41	572.14	1004.20	10.04
Min	175.18	120.97	64.49	192.62	1.93
Max	3145.29	2877.66	1631.73	3145.29	31.45
SD	550.66	513.48	355.43	565.11	5.65
3rd Quartile	1351.36	1217.56	788.91	1382.82	13.83

*Maximum ESD measured by UNFORS PSD that the highest from three point at the skin above the liver.

Table 4.9 The entrance surface dose (ESD) and effective dose (ED) determined by DAP methods.

ESD, ED	DAP meter readout values ($Gycm^2$)	Entrance surface dose , ESD(mGy)		Maximal ED (mSv)
		DAP ($Gycm^2$)	ESD (mGy)	
Average	222.60	289.07	969.90	9.70
Min	22.58	29.32	111.28	1.11
Max	537.43	697.89	2365.74	23.66
SD	114.62	148.85	527.08	5.27
3^{rd} Quartiles	294.44	382.35	1263.9	17.69

Table 4.10 The entrance surface dose (ESD) and effective dose (ED) determined by Unfors PSD methods.

ESD, ED	Entrance surface dose, ESD (mGy)			Maximal ESD dose (mGy)	Maximal ED (mSv)
	Left portion of liver	Middle portion of liver	Right portion of liver		
Average	968.66	848.41	572.14	1004.20	10.04
Min	175.18	120.97	64.49	192.62	1.93
Max	3145.29	2877.66	1631.73	3145.29	31.45
SD	550.66	513.48	355.43	565.11	5.65
3^{rd} Quartiles	1351.36	1217.56	788.91	1382.82	13.83

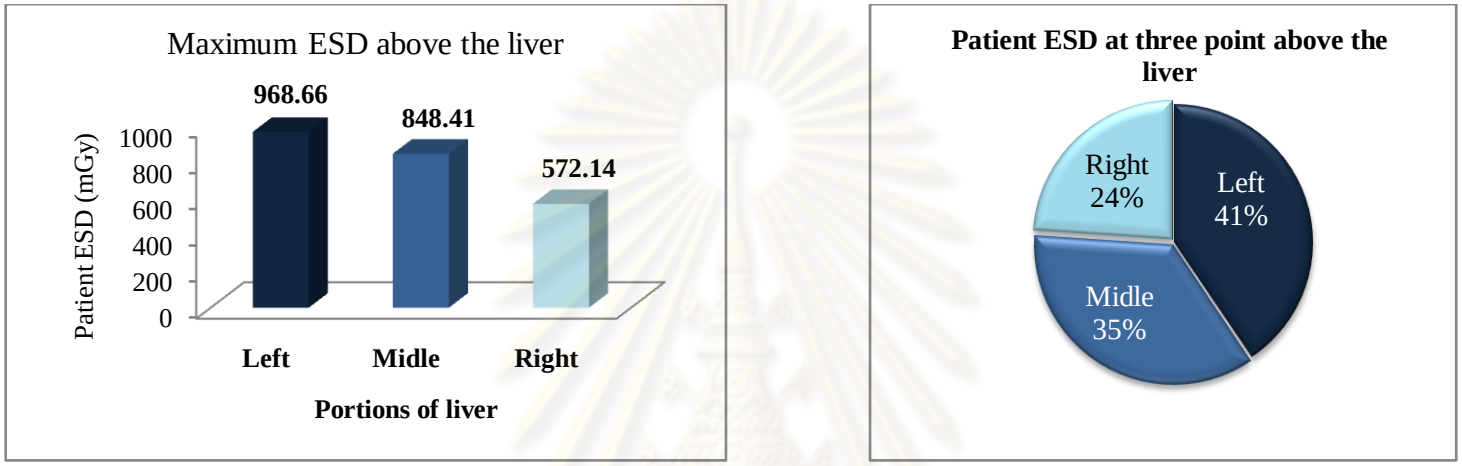


Figure 4.1 The peak entrance surface doses (ESD) at three points above the liver.

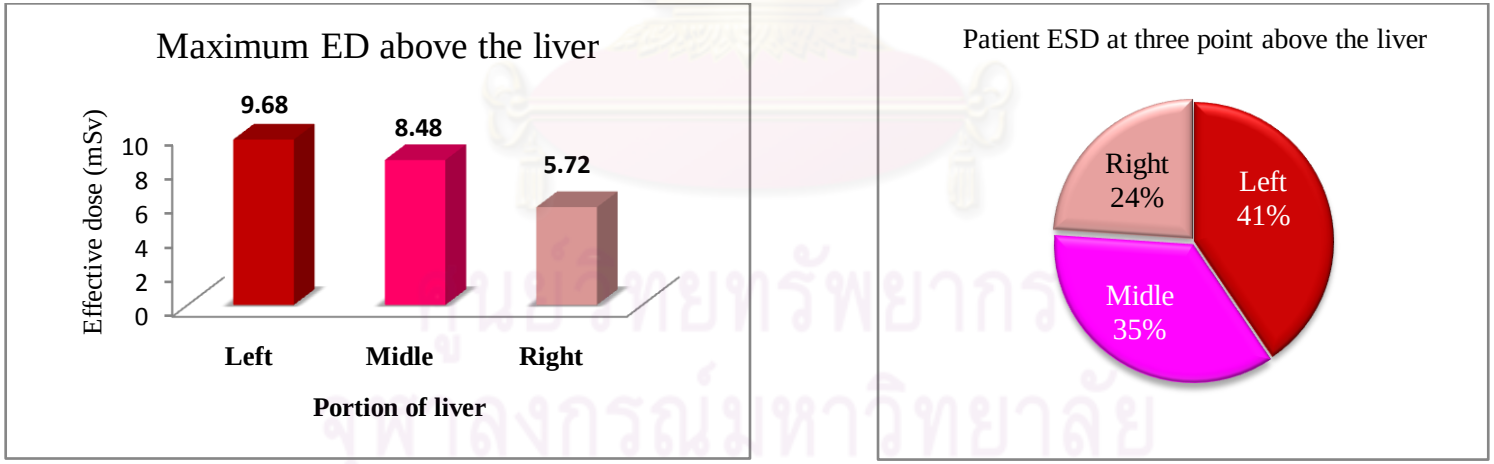


Figure 4.2 The peak effective dose(ED) at three points above the liver.

4.8 The entrance surface dose and the effective dose from fluoroscopic and the Digital Subtraction Angiography DSA (Table 4.11)

Table 4.11 The entrance surface dose from fluoroscopic time and the Digital Subtraction Angiography DSA.

	Fluoroscopic		Digital subtraction angiography DSA	
	ESD(mGy)	ED (mSv)	ESD(mGy)	ED (mSv)
Maximum*	321.06	3.21	501.78	5.01
Average**	221.59	2.21	430.52	4.30

* Maximum, determined by Unfors PSD
** Average, determined by DAP methods

4.9 The Complexity index.

The complexity index of each procedure from sixty-nine cases was recorded by the interventional radiologist. The data of complexity index was shown in APPENDIX E.

4.10 The correlation between average ESD and peak ESD.

The correlation between the average patient entrance surface dose (ESD) determined by DAP meter and the peak entrance surface dose determined by Unfors PSD of TOCE procedure is displayed in figure 4.3.

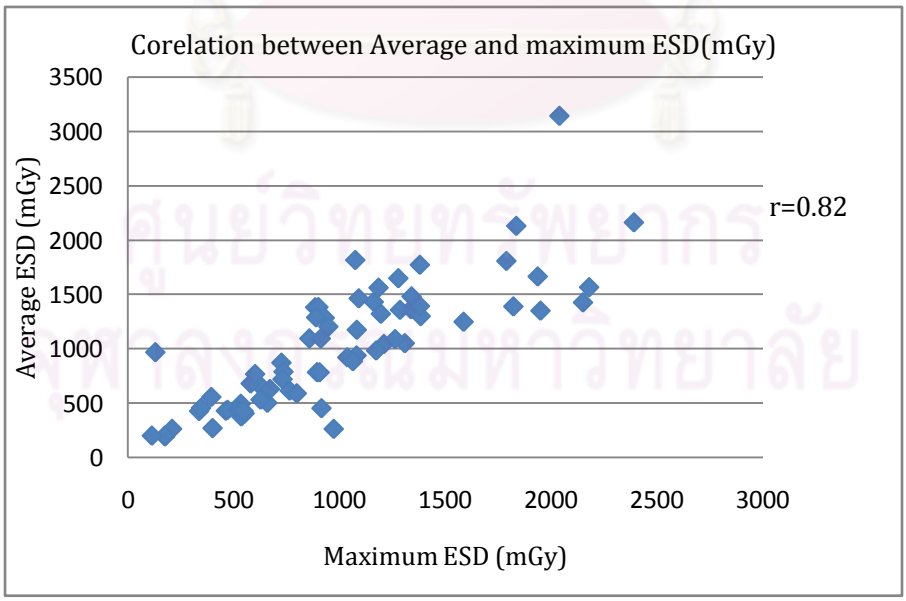


Figure 4.3 The correlation between the average doses determined by DAP meter and peak skin dose determined by Unfors PSD from 69 cases in TOCE procedure.

4.11 The relation between entrance surface dose and the affecting factors in TOCE procedure.

The scatter diagrams show the relation between the average entrance surface dose and the fluoroscopic time as in figure 4.4 the relation between DAP, $Gycm^2$, and fluoroscopic time in minute is shown in figure 4.5.

4.11.1 The relation between the peak ESD determined by Unfors PSD and fluoroscopic time.

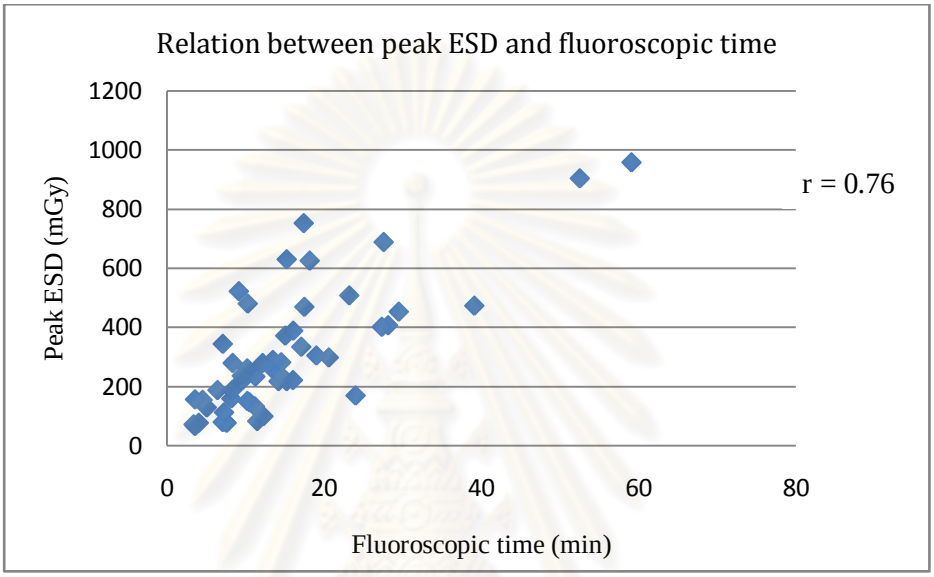


Figure 4.4 The relation between the peak ESD and fluoroscopic time in minute.

4.11.2 The relation between the average ESD determined by DAP ($Gycm^2$) and fluoroscopic time.

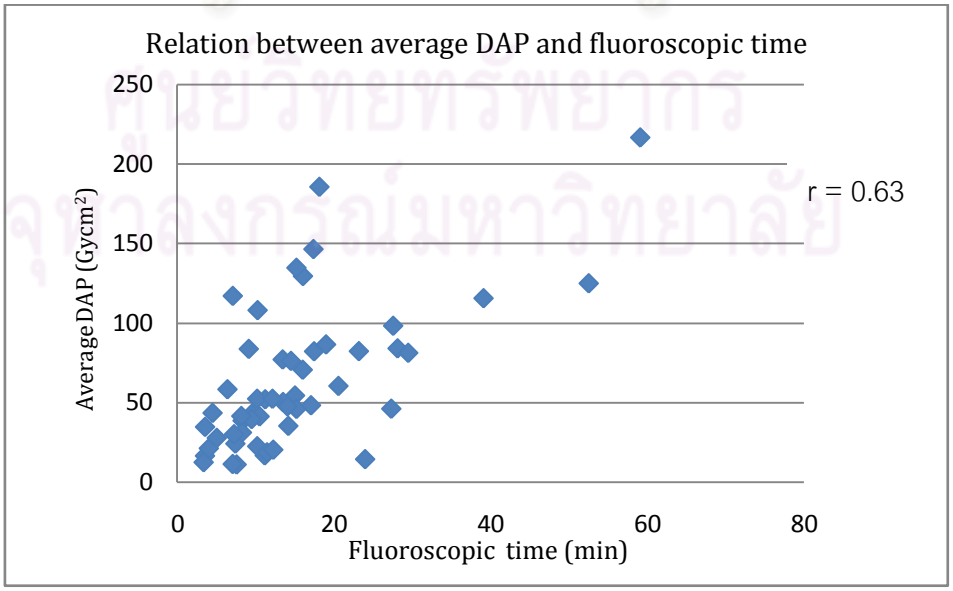


Figure 4.5 The relation between the average DAP and fluoroscopic time in minute.

4.11.3 The relation between the peak ESD determined by Unfors PSD and the number of frames.

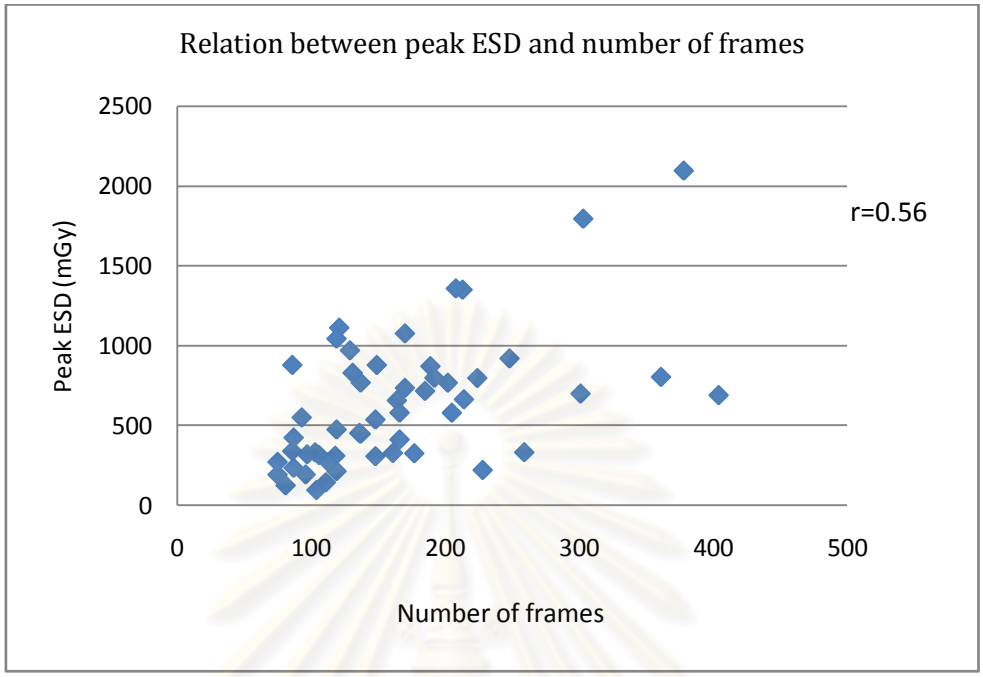


Figure 4.6 The relation between the peak ESD and number of frames.

4.11.4 The relation between the average ESD determined by DAP ($Gycm^2$) and the number of frames.

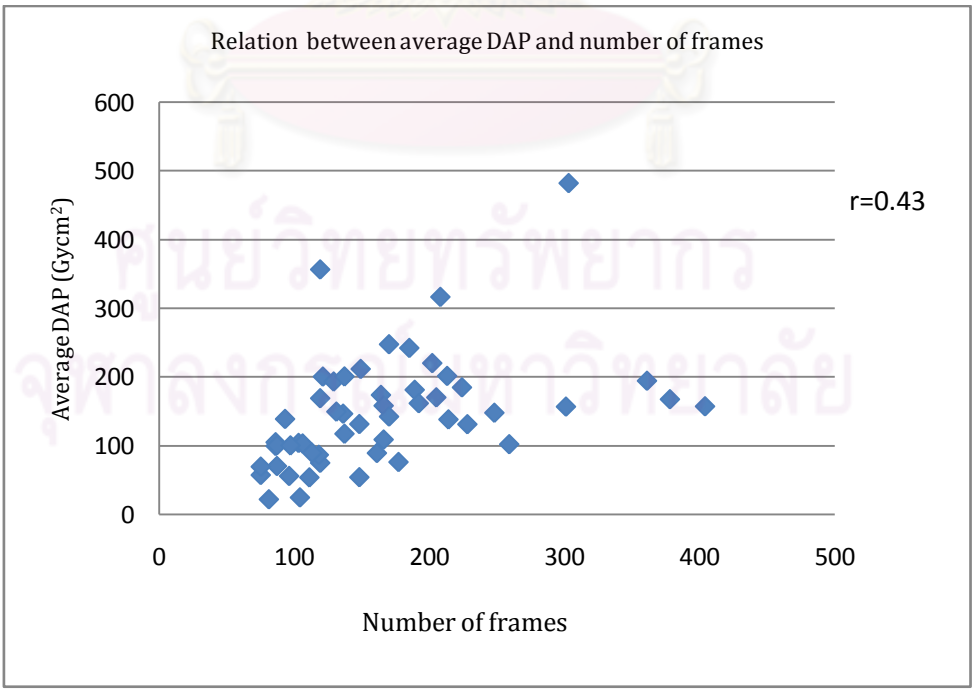


Figure 4.7 The relation between the average DAP and number of frames.

4.11.5 The relation between the peak ESD determined by Unfors PSD (mGy) and the patient BMI (kg/m^2)

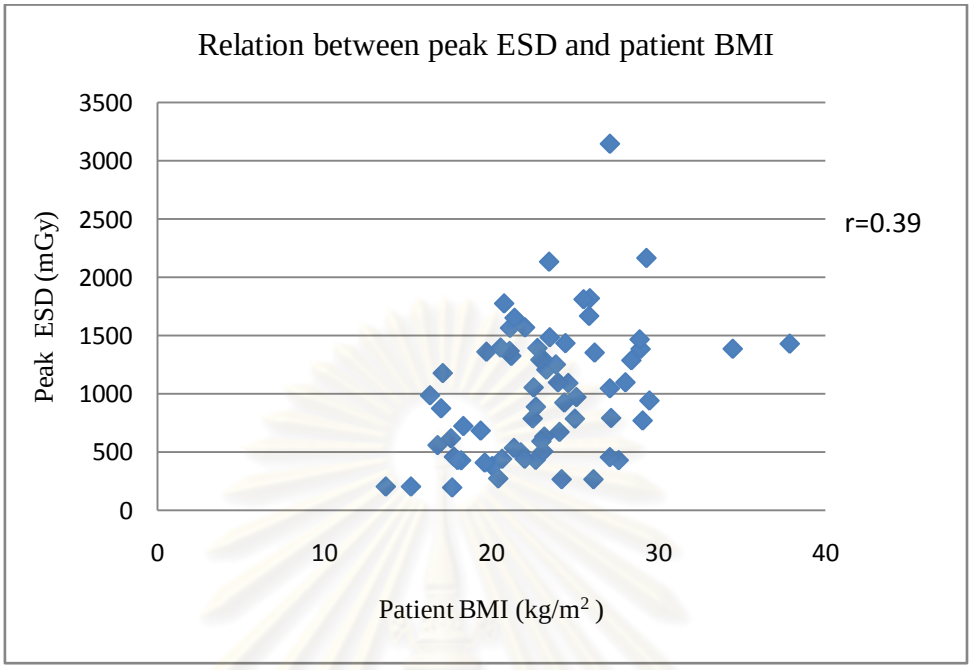


Figure 4.8 The relation between the peak ESD d and the patient BMI.

4.11.6 The relation between the average ESD determined by DAP ($Gycm^2$) and the patient BMI (kg/m^2)

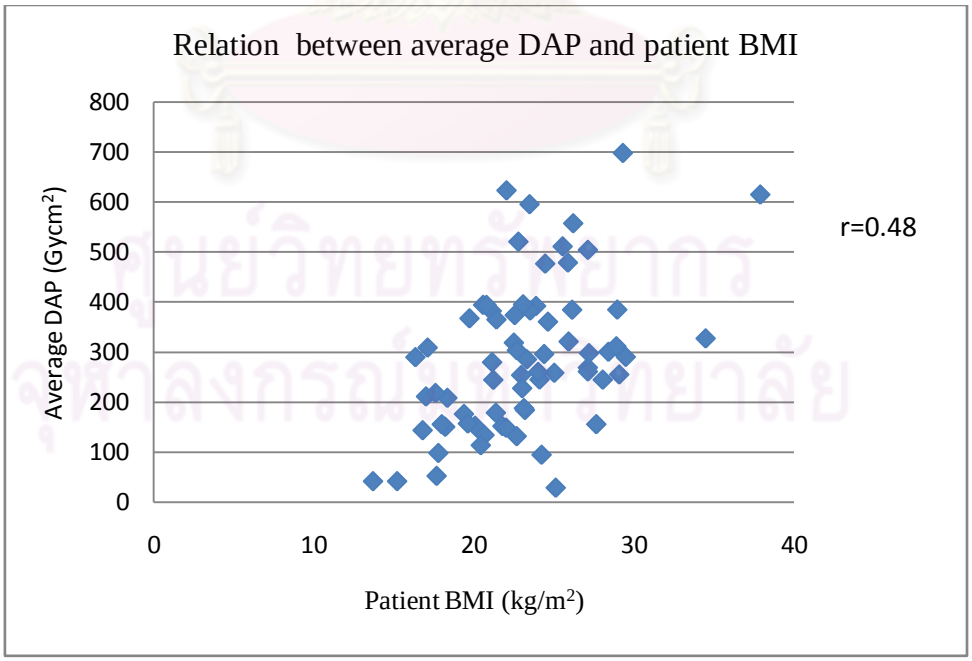


Figure 4.9 The relation between the average DAP and the patient BMI.

4.11.7 The relation between the peak ESD determined by Unfors PSD (mGy) and the experience of interventional radiologist.

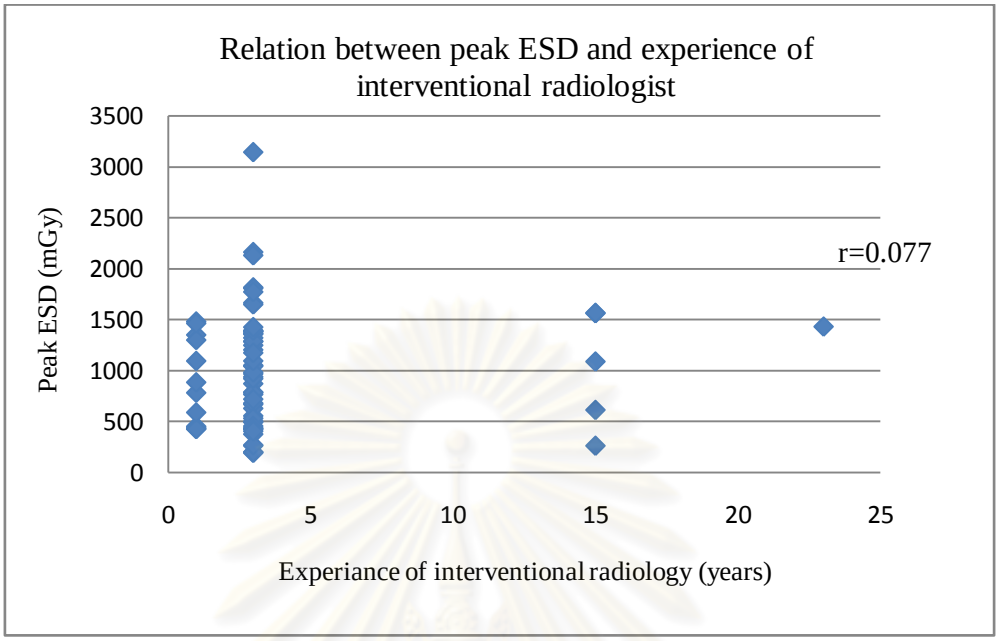


Figure 4.10 The relation between the peak ESD and the experience of interventional radiologist.

4.11.8 The relation between the average ESD determined by DAP (Gycm^2) and the experience of interventional radiologist.

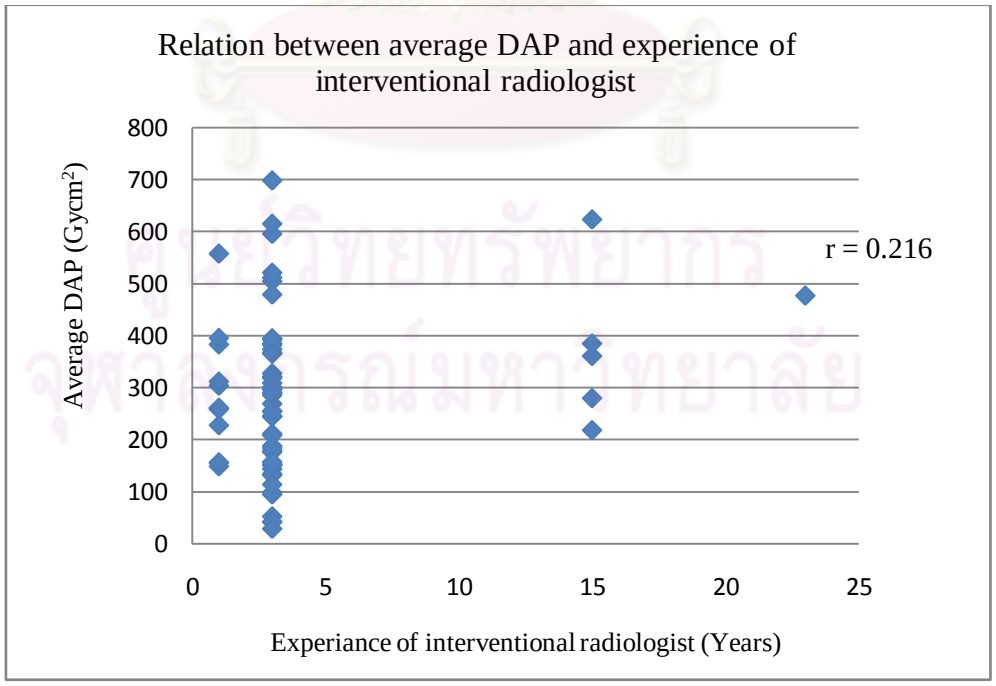


Figure4.11 The relation between the average DAP and the experience of interventional radiologist.

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Discussion

5.1.1 Performance of digital flat-panel system.

From the dose assessment of digital flat-panel system, the low mode can reduce the ESAK of 79.4 % of the same field size as compare with normal mode and 81.9 % as compare with high mode, otherwise, the dose increase only 11.8% as compare between normal mode and high mode.

The magnifications of each field size increase radiation dose as 16.11% in low mode, 15.01% in normal mode and 13.99% in high mode. Thus, low mode should be selected for small size patient with optimized parameters to reduce the radiation dose.

The automatic brightness control test (ABC), the field size assessment and maximum dose rate assessment were within acceptable limit

The table attenuation factor was 5.9 % and the HVL was 6.2 mmAl at 80 kV, the value was used to determine the entrance surface dose.

5.1.2 The patients

The patient who received the highest entrance surface dose (ESD) at 3.14 Gy was a 62 year old female. This procedure was her fourth time with TOCE procedure without success as the high complexity index as the previous time. The X-per CT procedure was performed to identify the selected vascular.

In this study, the accumulative fluoroscopic time was 59 minutes. The number of frames using for DSA were 134 frames and 244 frames for X-per CT resulting in 378 frames in total. The average ESD was 2.37 Gy and the maximum ESD was 3.14 Gy, thus, the complexity index and the fluoroscopic time are the major factors affecting the patients ESD. (What about number of frames as mentioned?)

During the procedure to identify the selected vascular supply tumor, the X-per CT was used in two patients which increasing the surface dose. The radiation dose increases because; the detector rotates around the patient body and exposed radiography. The exposure was 60 frames per second. The filters used were;

- Selected Exposure Pre Filter 9.00mmCu+0.00 mmAl
- Selected Fluo Pre Filter 0.40 mmCu+1.00 mmAl

Three from sixty-nine patients received repeated studies. The accumulated dose should be determined to ensure that the ESD does not exceed the threshold level for skin injury (Table 5.1).The dose rate from TOCE procedure was 13.86 $Gycm^2$/min.

Table 5.1 The ESD of the patients with repeated TOCE procedure

No	Study number	Date d/m/y	Flu time (min)	ESD (mGy)		ED (mSv)	
				Peak (PSD)	Average (DAP)	Peak (PSD)	Average (DAP)
1	1st	14/8/2009	10.52	968.8	127.47	9.69	1.27
	2nd	9/10/2009	13.15	1300.78	1368.56	13.01	13.69
	Total		23.67	**2269.58**	1496.03	22.70	14.96
2	1st	21/8/2009	14.08	494.02	527.32	4.94	5.27
	2nd	2/10/2009	8.27	532.17	619.62	5.32	6.20
	Total		22.35	1026.19	1146.94	10.26	11.47
3	1st	6/10/2009	4.52	376.85	529.49	3.77	5.29
	2nd	16/11/2009	11.48	406.23	545.14	4.06	5.45
	Total		16	783.08	1074.63	7.83	10.74

5.1.3 The ESD determined by DAP meter.

The determination of the average entrance surface dose (ESD) by DAP meter during TOCE procedure, the average DAP readout was 222.6Gycm^2 the range was 22.58-537.43 Gycm^2, the 3rdquartile was 294.43 Gycm^2. The average ESD determined by DAP meter included the back-scatter factor was 969.90mGy with the range of 111.28-2365.74 mGy and the 3rd quartile was 1263.9 mGy .The ESD is the accumulation of irradiated skin dose where the average dose could be obtained. The accuracy on the skin exposed area is limited as the FOV and the tube angulations are variable during TOCE procedure.

In this study, four from sixty-nine patients received the skin dose exceed the threshold level for skin injury. The results were compared with other 11 studies as shown in table 5.2. Our study shows the second highest fluoroscopic time of 59.1 minute while the DAP was the 5th of 537.4 Gy.cm^2. The average DAP was 222.6 Gy.cm^2 which was second highest after Svetlana S. study of 233 Gycm^2. The average fluoroscopic time was 16 minutes which was the 4th shortest from all study. The therapeutic type of TOCE study resulted in the highest entrance surface dose (ESD).

The results were compared with the DAP readouts between digital flat-panel and conventional system from TOCE procedures at interventional radiology unit, King Chulalongkorn Memorial Hospital **[18]** and other institutes. Our study shows the range of fluoroscopic time and DAP meter readouts from TOCE procedures during digital flat-panel system of 3.38-59.1 minutes and 22.5-537.5 Gycm^2,and from Image intensifier system the range was 2.40-48 minutes , DAP readouts was 24.3-381.6 Gycm^2 . The maximal skin dose was higher in Philips FD 20 of digital flat-panel detector than with Siemens Polytar of conventional system as the result of R**.**Ruiz-Crucess.et al, **[19]** as in Table 5.2**.** Although, the result showed that the Flat-panel cannot reduce the radiation dose when compare the conventional system, there were many parameters such as the acquisition mode, dose rate, FOV, the exposure technique, the complexity, that affected the result.

Table 5.2 Comparison of DAP readouts with other studies during TOCE procedure.

Author	Year	Country	Detector system	Type	No. of patients	Fluoroscopic time (min)		DAP ($Gy.cm^2$)	
						Mean	Range	Mean	Range or upper limit
Kumkrue et al,[18]	2004	Thailand	II	Therapeutic	21	NA	2.4-48	NA	24.3-**381.6**
This study	2010	Thailand	FPD	Therapeutic	69	**16.0**	3.38-**59.1**	**222**±114	22.5-**537.4**
S Suzuki et al,[15]	2005	Japan	FPD	Both	25	17.9	NA	73	36.9-133.3
R.Ruiz-Crucess.et al,[19]	1997	Spain	II	Both	9	15.2±5.11	NA	73.6+17.6	97.89-47.46
			FPD	Both	10	9.8±5.35	NA	88.3±17.3	51.23-93.80
B Sapiin et al,[20]	2004	Malaysia	NA	Diagnostic	6	29.7±4.6	19.6-45.9	127	30.0-237.9
			NA	Therapeutic	7	17.2±12	4.3-53.2	88	49.3-125.5
Williams J R [21]	1997	Malaysia	NA	Diagnostic	41	NA	NA	97.9	297.4
			NA	Therapeutic	27	NA	NA	105	NA
BJ Mc et al, [22]	1998	Saudi	II	Diagnostic	7	12.1	3.6-41.8	136	17.6-267
		Arabia	II	Therapeutic	16	18.4	6.6-58.8	168	42-**609**
BOR D et al, [23]	2004	Turkey	II	Diagnostic	5	3.2	1-4.7	52	3-167
			II	Therapeutic	14	**7.7**	1.8-13	77	16.6-240
Svetlana S et al [24]	2010	Russia	FPD	Diagnostic	49	2±2.1	0.2-9.8	106±88	11-335
			FPD	Therapeutic	44	14.8±16.2	0.2-9.8	**233**±221	16-**855**
E. Papageorgiou et al, [25]	2010	Greece	FPD	Therapeutic	25	10.5±8.4	1.3-29.4	136±83	15-341
EliseoVano et al, [26]	2009	Spain	NA	Therapeutic	151	**19.8**±11	2.8-**80**	216±176	27.4-**830**

II; Image intensifier detector (Conventional system), FPD; Flat-panel detector system

5.1.4 The ESD determined by Unfors PSD

The determination of patient entrance surface dose (ESD) by solid state detectors Unfors PSD during TOCE procedure from digital flat-panel system, (Philips Allura FD 20) the maximum of peak skin dose from three points above the liver was 1004.2; the range was 192.62-3145.29 mGy. The left portion of liver, the peak skin dose was 968.66mGy, the range was 175.18 - 3145.29 mGy, the right portion of liver, the peak skin dose was 572.14mGy the range was 64.49 - 1631.73 mGy and the middle portion of liver, the peak skin dose was 848.41mGy the range was 120.97 - 2877.66 mGy**.** From this study the left lobe of the liver received the dose higher than the middle and right lobe of the liver. The left received 42 %, the middle lobe 35 % and the right 24 %. The highest dose results in the superimpose of the spine and the abdominal aorta which is the area to identify the selected vascular supply tumor. Therefore, the high density organ affected the radiation dose to the skin. In this study 3 from 69 patients received the ESD exceed the threshold for skin injury.

5.1.5 The effective dose (ED)

The effective dose at the skin over the liver was calculated by applying the tissue weighting factor from ICRP 103 as shown in APPENDIX A. The conversion factors for the effective dose and the DAP was 0.043 $mSv.Gy^{-1}cm^{-2}$.

The solid state dosemeter is most suitable for entrance surface dose measurement for its small size of detector, easily use and there was no need to estimate the surface area exposed as in DAP method. As DAP meter shows all exposures readout, some exposure is sometimes not at the target organ. Furthermore, the x-ray tube moves during the procedure resulting in the inaccuracy of the exposed area as well as inaccuracy of the average skin dose. However, solid state detector could identify the result in limited area because of the small size of detector. Thus, the radiochromic film (Gafchromic film) should be added into this procedure to confirm the peak skin dose the patient received.

5.1.6 The relationship between DAP method and solid state detectors.

The result shows the linear correlation between the estimated dose from DAP meter and the peak skin dose from Unfors PSD with good correlation of r=0.82. The peak skin dose is higher than the estimated dose from DAP meter. As the DAP is the cumulative dose from every exposure to parts of the patient, so the dose could be estimated from the average radiation areas, while PSD measured at three points on the real exposed skin. Both results compliment to each other and benefit the patient, especially the maximum exceeds the threshold level of skin injury. Table 5.5 shows the Pearson correlation coefficient (r) between the peak ESD (Unfors PSD), average ESD and factors affecting in TOCE procedure.

The relationship, between the patients ESD (peak, average) and the fluoroscopic time are 0.63 and 0.76, the relationship between the patient ESD (peak, average) and the number of frames are 0.56 and 0.43, the relationship between the patients ESD (peak, average) and the patient BMI are 0.39 and 0.48, the relationship between the patients ESD (peak, average) and the experience of interventional radiologist are 0.07 and 0.41 respectively. Thus, the patient BMI and the experience of interventional radiologist are poor correlation.

Table 5.3 Pearson correlation coefficient (r) between the peak ESD (Unfors PSD), average ESD (DAP) and factors affecting in TOCE procedure

Influenced	Pearson correlation coefficient (r)		95%CI	Range for true population mean
	Peak ESD*	Average ESD**		
Fluoroscopic time (min)	0.76	0.63	$\pm$ 2.66	13.04-18.72
Number of frames (frames)	0.56	0.43	$\pm$ 22.32	158.49-203.13
Patient BMI (kg/m^2)	0.39	0.48	$\pm$ 1.03	22.1-24.16
Experience of interventional radiologist(years)	0.07	0.41	$\pm$ 0.96	2.85-4.77

*Peak ESD determined by Unfors PSD
**Average ESD determined by DAP meter

5.2 Conclusions

Among sixty-nine patients, the average effective dose at the skin over the liver during TOCE for Hepatocellular Carcinoma (HCC) using a new angiographic unit with a digital flat-panel system as determined by DAP meter and PSD methods were 6.96 and 10.04 mSv respectively. The third quartile of the effective dose represents the dose reference level (DRL) for TOCE studied at King Chulalongkorn Memorial Hospital was 12.63 and 13.82 mSv. . Seventeen patients received the entrance surface dose exceeding the DRL. Two from sixty-nine patients received the entrance surface dose exceeding the threshold for radiation skin injuries determined by PSD and DAP methods.. The follow-up patients are recommended.

The relationship between the effective dose determined by PSD Unfors and the dose area product (DAP) methods is good correlation of r = 0.82., while the relation between ESD and fluoroscopic time is 0.76 (PSD) and 0.63 (DAP). Even though the correlation between the peak ESD and radiologist experience was 0.07 as in figure 4.10, the peak ESD was highest examined by the radiologist of 3 year experience and become low with high experience radiologist of 23 years. This also confirms by the DAP data in figure 4.11. The conversion factors for the effective dose and the DAP was 0.043 $mSv.Gy^{-1}cm^{-2}$.

5.3 Recommendations

The serious radiation skin injuries to patients caused by interventional procedures should be avoided. Acute radiation doses to patients cause erythema at 2 Gy, temporary epilation at 3 Gy, permanent epilation at 7 Gy, and dermal necrosis at 18 Gy **[17].** Methods of reducing skin doses include the followings:

- Limiting the number of acquired images, fluoroscopy time, and dose rate;
- Increasing tube potential and tube filtration
- Minimizing the distance between the image intensifier and the patient
- Maximizing the distance between the X-ray tube and the patient
- Collimating the radiation field as much as possible
- Using pulsed fluoroscopy and last image hold.
- In addition, different beam incidences should be considered if the procedure is unexpectedly prolonged**.[25]**

In this study, the awareness of the interventional radiologist of patient dose, optimize the clinical procedures and the dose settings of the x-ray units in this specialty are recommended.

The radiologists are recommended for the awareness the radiation skin injury to patients caused by the TOCE procedure. The ESD should be recorded in every studies and the ED could be determined using the conversion factor apply to DAP values when the PSD is not available.

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APPENDICES

APPENDIX A

Table I. W_T – new recommendations from Impact of the new ICRP recommendations on external radiation protection dosimetry

ORGAN	ICRP26	ICRP60	ICRP103
Gonads	0.25	0.20	0.08
Bone marrow (red)	0.12	0.12	0.12
Lung	0.12	0.12	0.12
Breast	0.15	0.05	0.12
Thyroid	0.03	0.05	0.04
Bone surfaces	0.03	0.01	0.01
Remainder	0.30	0.05	0.12
Colon	-	0.12	0.12
Stomach	-	0.12	0.12
Bladder	-	0.05	0.04
Liver	-	0.05	0.04
Oesophagus	-	0.05	0.04
Skin	-	0.01	0.01
Salivary glands	-	-	0.01
Brain	-	-	0.01

APPENDIX B

Case Record Form

TABLE II Clinical data collection sheet for TOCE procedure in vascular and intervention radiology unit

Clinical data collection sheet for TOCE procedure in vascular and intervention radiology unit		
Facility identification		
Equipment ID		
Initial DAP setting		
Initial cumulative fluoroscopy time		
Date		
Patient Study Number		
height		
weight		
gender		
Age		
Portal film in place?		
PSD in place		
Start time		
Fluoroscopy mode		
End time		
DAP readout at end		
Cumulative fluoroscopy time at end		
Number of frame		
Frame rate		
Kvp		
mA		
FOV		
Filter		
Dose from PSD 1. Right lobe 2. Left lobe 3. Middle lobe		
Calculated patient skin dose		
Data Collection		

TABLE III Clinical Data Collection for TOCE Procedure

Pt No.	Age	Gender (M/F)	DATE	Pt BMI	Dose from PSD (Gy)	dose from DAP (Gy cm2)	Flu time	kVp	mA	Flu mode	Frame rate/no of frame	FOV	Filter
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													

TABLE IV Complexity index of TOCE procedure

Complexity index of TOCE procedure	
Pt No.	
Date (D/M/Y)	
Age : M/F	
Wt(kg) : Ht(cm)	
Cooperation/Breath hold/Movement (y/n)	
Disease TYPE A-E	
Procedure Elective/Emergency	
No. of tumor	
No. of bleeder	
Tumor Diameter(cm)	
Hepatic segment(s) segment 1 to 8	
Angulations <45/45-90/>90	
Branching 0:no side branch 1: bifurcation 2 :trifurcation	
Tortuosity mild 0-1 curves moderate 2-3 severe : more than 3	
Invasion (0-3) 0:normal 1:2nd tributary 2:1st tributary 3: main	
Portal vein : AP shunt (y/n)	
No of catheter used	
Conventional/Micro	
No of guide wire used	
Embolic material	
Anticancer drug	
Complication during procedure	
Operators Experience in interventional, yrs.	
visual	
Total index	

APPENDIX C

Patient Information Sheet

เอกสารข้อมูลคำอธิบายสำหรับผู้ป่วยที่เข้าร่วมการวิจัย

การศึกษา การวัดปริมาณรังสียังผลของผู้ป่วยในการตรวจ ทีโอซีอี (TOCE) ด้วยเครื่องเอกซเรย์ระบบดิจิทัล แฟลตพาเนล

เรียน ผู้เข้าร่วมวิจัยทุกท่าน

ท่านได้รับเชิญจากผู้วิจัยให้เข้าร่วมการศึกษาเพื่อวัดปริมาณรังสียังผลของผู้ป่วยที่ได้รับการตรวจรักษาทีโอซีอี (TOCE) โดยใช้ เครื่องวัดที่เป็นชนิดโซลิดเสตดและ แดพมิเตอร์ ก่อนที่ท่านจะตกลงเข้าร่วมการศึกษาดังกล่าว ขอเรียนให้ท่านทราบถึงเหตุผลและรายละเอียดของการศึกษาวิจัย ในครั้งนี้

ผู้ป่วยที่เข้ารับการตรวจที โอซีอี (TOCE) ซึ่งเป็นหนึ่งในการตรวจทางด้านรังสีร่วมรักษาโดยใช้การฉายรังสีแบบต่อเนื่อง (Fluoroscopy) เป็นเครื่องมือในการตรวจนั้น จะมีความเสี่ยงที่จะได้รับปริมาณรังสีสูงกว่าการตรวจวินิจฉัยโดยทั่วไป และปริมาณที่ได้รับจะอยู่ในระดับเกณฑ์ที่สามารถยอมรับได้หรือไม่นั้นเป็นสิ่งที่น่าศึกษาอย่างยิ่ง

ดังนั้นการศึกษาวิจัยในครั้งนี้ มีวัตถุประสงค์เพื่อ วัดปริมาณรังสีที่ผิวหนังของผู้ป่วยต่อการตรวจหรือรักษาแต่ละครั้งว่ามีปริมาณเท่าไร เพื่อไม่ให้เกินปริมาณรังสีสูงสุดที่ผู้ป่วยสามารถรับได้และมีวิธีการลดปริมาณรังสีที่ผู้ป่วยได้รับอย่างไรในการตรวจแต่ละครั้ง

ในการวัดปริมาณรังสีนั้นจะใช้เครื่องวัดรังสีชนิดที่เป็นโซลิดเสตด (Unfors PSD) ซึ่งมีลักษณะเป็นแผ่นตรวจจับรังสี ขนาด 1.5 เซนติเมตร มีสายต่อเข้าเครื่องอ่านโดยตรงและสามารถอ่านค่าได้ทันที ในการวัดโดยใช้เครื่องวัดโซลิตเสตด (Unfors PSD)นั้นจะใช้แผ่นวัด ติดที่ตำแหน่งด้านหลังของผู้ป่วยให้ตรงกับตำแหน่งของตับ 3 ตำแหน่ง คือ ตับกลีบซ้าย กลีบขวา และตรงกลาง และสำหรับการวัดโดยใช้แดพมิเตอร์ (DAP meter) ซึ่งเป็นเครื่องมือที่ใช้วัดปริมาณรังสีที่ออกมาจากหลอดเอกซเรย์โดยตรง จะนำฟิล์มวางบนเตียงใต้ตัวผู้ป่วยบนเตียงเอกซเรย์ตรงบริเวณที่รังสีผ่านตัวผู้ป่วย ส่วนหัววัดจะติดอยู่ที่หลอดเอกซเรย์โดยเครื่องอ่านค่าจะแยกออกมาต่างหาก ซึ่งอุปกรณ์ทั้ง 2 ชนิดนี้จะไม่รบกวนหรือเป็นอุปสรรค ทั้งผู้ป่วยและเจ้าหน้าที่ในขณะปฏิบัติงาน

หากท่านตกลงที่จะเข้าร่วมการศึกษาวิจัยนี้ จะมีข้อมูลและข้อปฏิบัติร่วมดังต่อไปนี้

1. ในการทำการวิจัยในครั้งนี้จะทำการวิจัยในอาสาสมัครทั้งหมด 69 ท่าน
2. ท่านไม่ต้องเสียค่าใช้จ่ายใดๆ เพื่อการวัดค่าปริมาณรังสีดังกล่าว
3. ก่อนเริ่มการตรวจในแต่ละครั้ง ผู้วิจัยจะติดเครื่องมือคือ เครื่องตรวจชนิดโซลิตเสตด บริเวณหลังผู้ป่วย 3 จุด และ แผ่นฟิล์มวางบนเตียงใต้ตัวผู้ป่วยบนเตียงเอกซเรย์ตรงบริเวณที่รังสีผ่านตัวผู้ป่วย

4. ท่านอาจเกิดการระคายเคืองจากเครื่องมือและอุปการณ์ที่ใช้ในการติดบริเวณแผ่นหลังเพื่อตรวจวัดรังสีเพียงเล็กน้อย
5. หากเกิดอันตรายใดๆ จากการวิจัยดังกล่าว ผู้เข้าร่วมวิจัยจะได้รับการ รักษาพยาบาล โดยไม่เสียค่าใช้จ่าย (และจะได้รับการชดเชยจากผู้วิจัย)
6. หลังจากที่แพทย์และเจ้าหน้าที่ทำการตรวจหรือการรักษาเสร็จในแต่ละการตรวจ ผู้วิจัยจะทำการเก็บฟิล์มและอ่านข้อมูลของเครื่องมือวัดและนำค่าที่ได้จาแดพมิเตอร์และเครื่องมือวัดชนิดโซลิตเสตดมาทำการคำนวณหาปริมาณรังสีที่ผู้ป่วยได้รับในการตรวจครั้งนั้นๆ
7. การเข้าร่วมการศึกษาวิจัยนี้ เป็นไปโดยสมัครใจ ท่านอาจจะปฏิเสธที่จะเข้าร่วมการวิจัย หรือถอนตัวจากการวิจัยนี้ได้ทุกเมื่อโดยไม่จำเป็นต้องแจ้งเหตุผล
8. ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะเกี่ยวกับตัวผู้เข้าร่วมวิจัยเป็นความลับโดยจะไม่มีการเปิดเผยชื่อของท่านตามกฎหมาย และจะเปิดเผยได้เมื่อได้รับการยินยอมจากผู้เข้าร่วมวิจัยเท่านั้น บุคคลอื่นในนามของผู้สนับสนุนการวิจัย คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน อาจจะได้รับอนุญาตให้เข้ามาตรวจและประมวลข้อมูลส่วนตัวของผู้เข้าร่วมวิจัย ทั้งนี้จะต้องกระทำไปเพื่อตรวจสอบความถูกต้องของข้อมูลเท่านั้นและจะต้องได้รับคำยินยอมที่จะให้มีการตรวจสอบข้อมูลจากผู้เข้าร่วมวิจัยเท่านั้น

ประการสำคัญที่ท่านควรทราบ คือ ผลของการศึกษาวิจัยนี้ จะใช้สำหรับวัตถุประสงค์ทางวิชาการและความปลอดภัยในการตรวจวินิจฉัยและรักษาผู้ป่วยทางรังสีเท่านั้น

หากต้องการติดต่อผู้วิจัย สอบถามต่างๆหรือพบปัญหาและข้อสงสัยประการใด กรุณาติดต่อ นางสาวพิมณัฏฐา สิทธิพันธ์ โทร 085-3254120 ซึ่งยินดีให้คำตอบแก่ท่านทุกเมื่อ

หากท่านไม่ได้รับการชดเชยอันควรต่อการบาดเจ็บหรือเจ็บป่วยที่เกิดขึ้น โดยตรงจากการวิจัย หรือท่านไม่ได้รับการปฏิบัติตามที่ปรากฏในเอกสารข้อมูลคำอธิบายสำหรับผู้เข้าร่วมในการวิจัย ท่านสามารถร้องเรียนได้ที่ คณะกรรมการจริยธรรมการวิจัย คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย ตึกอานันทมหิดลชั้น 3 โรงพยาบาลจุฬาลงกรณ์ ถนนพระราม 4 ปทุมวัน กรุงเทพฯ 10330 โทร 0-2256-4455 ต่อ 14, 15 ในเวลาราชการ

ขอขอบคุณในความร่วมมือของท่านมา ณ ที่นี้

ใบยินยอมเข้าร่วมการวิจัย (Consent form)

การวิจัย เรื่อง การวัดปริมาณรังสียังผลของผู้ป่วยในการตรวจ ทีโอซีอี (TOCE) ด้วยเครื่องเอกซเรย์ระบบดิจิทัลแฟลตพาแนล

วันที่ให้คำยินยอม วันที่ .....เดือน.....พ.ศ.....

ข้าพเจ้าได้รับสำเนาเอกสารแสดงความยินยอมเข้าร่วมโครงการวิจัยที่ข้าพเจ้าได้ลงนาม และวันที่พร้อมด้วยเอกสารข้อมูลสำหรับผู้เข้าร่วมวิจัย ทั้งนี้ก่อนที่จะลงนามในใบยินยอมให้ทำการวิจัยนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการทำวิจัย วิธีการวิจัย อันตรายหรืออาการที่อาจเกิดขึ้นจากการทำการวิจัย รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียดและมีความเข้าใจดีแล้ว ข้าพเจ้ามีเวลาและโอกาสเพียงพอในการซักถามข้อสงสัยทั้งหมดจนมีความเข้าใจอย่างดีแล้วโดยผู้วิจัยได้ตอบคำถามต่างๆที่ข้าพเจ้าสงสัยด้วยความเต็มใจไม่ปิดบังซ่อนเร้นจนข้าพเจ้าพอใจ

ข้าพเจ้ามีสิทธิที่จะบอกเลิกการเข้าร่วมในโครงการวิจัยนี้เมื่อใดก็ได้ และเข้าร่วมโครงการนี้โดยสมัครใจ และการบอกเลิกการเข้าร่วมวิจัยนี้ จะไม่มีผลใดๆ ต่อข้าพเจ้า

ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะเกี่ยวกับตัวข้าพเจ้าเป็นความลับ และจะเปิดเผยได้เฉพาะที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆ ที่เกี่ยวข้องกระทำได้เฉพาะกรณีที่จำเป็น ด้วยเหตุผลทางวิชาการเท่านั้นและจะต้องได้รับคำยินยอมที่จะให้มีการตรวจสอบข้อมูลจากข้าพเจ้าเท่านั้น

ข้าพเจ้าได้อ่านข้อความข้างต้นแล้ว และมีความเข้าใจดีทุกประการ และได้ลงนามในใบยินยอมนี้ด้วยความเต็มใจ

ลงนาม.....ผู้ยินยอม

(.....)

วันที่ .....เดือน.....พ.ศ.....

ลงนาม.....พยาน

(.....)

วันที่ .....เดือน.....พ.ศ.....

ลงนาม.....ผู้ทำวิจัย

(.....)

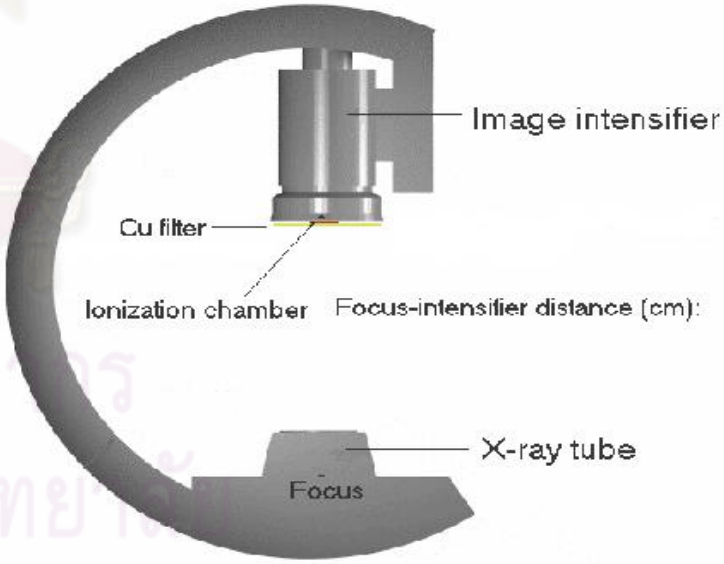
วันที่ .....เดือน.....พ.ศ.....

APPENDIX D

EQUIPMENT PERFORMANCE FOR FLUOROSCOPY EQUIPMENT

Hospital	King Chulalongkorn Memorial Hospital
X-ray unit	Philips Allura Xper FD 20
Room	Vascular and Interventional Radiology Unit
Report umber	1
Date	21 Mar 2009
Test performed by	Pimnuttha Sitthiphan

Single plane
Rotating Anode, Pulse Fluoroscopy 3.75, 7.5, 15/30/p/s
Small focal spot: 0.4 Large focal spot: 0.7
Anode heat storage capacity 2.4 MHU
Filter 1mmAl, .0.2, 0.5, 1.0 mmCu
Rectangular Collimator
Cesium Iodine Scintilator use Amorphous silicon array max FOV 30x38cm
Carbon fiber table minimum height adjust 28 cm minimum weight 225 kg
Table at 0 position, minimum distance from Focus to table 52 cm and table to FD 48.0 cm
Manufactured January 2008



DOSE ASSESSMENT

	set	Measure	Error
Focus –flat-panel detector (cm)	90-120	87-117	3.3 %
Patient dose measurement: Focus-Patient Dist		70 cm	
Entrance II dose measurement: Focus-Ion ch. Dist		31 cm	

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu)	Field size (cm)	kV	mA	Added Filtration (mm Cu)	(Patient entrance surface air kerma) Copper filter entrance air kerma (µGy/s)	Patient entrance surface air kerma at 70 cm (including backscatter) (µGy/s)	Phantom
Flu 1 low		15/s	2	48	70	3.4		35.57	49.798	Cu
				42	72	3.9		53.18	74.452	
				37	73	4.2		63.46	88.844	
				31	74	4.6		58.83	82.362	
				27	75	5.1		70.42	98.588	
				22	77	5.9		88.78	124.292	
				19	79	6.6		104.6	146.44	
				15	81	7.3		128.9	180.46	

DOSE ASSESSMENT

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu)	Field size (cm)	kV	mA	Added Filtration (mm Cu)	(Patient entrance surface air kerma) Copper filter entrance air kerma (μGy/s)	Patient entrance surface air kerma at 70 cm (including backscatter) (μGy/s)	Phantom
Flu 2		15/s	2	48	67	8.1		207.4	290.36	Cu
				42	69	9.1		248.0	347.2	
				37	69	9.4		268.0	375.2	
				31	71	10.2		303.7	425.18	
				27	72	11.0		346.6	485.24	
				22	75	12.4		439.2	614.88	
				19	76	13.4		491.8	688.52	
				15	80	15.1		623.0	872.2	
Flu 3		30/s	2	48	69	8.3		237.2	332.08	Cu
				42	70	9.3		284.0	397.6	
				37	71	10.2		306.1	428.54	
				31	72	11.0		346.3	484.82	
				27	74	11.8		399.9	559.86	
				22	76	13.1		483.6	677.04	
				19	78	14.4		564.5	790.3	
				15	82	14.9		685.3	959.42	

DOSE ASSESSMENT

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu)	Field size (cm)	kV	mA	Added Filtration (mm Cu)	(Patient entrance surface air kerma) Copper filter entrance air kerma (μGy/s)	Patient entrance surface air kerma at 70 cm (including backscatter)	Phantom
Single shot			2	48	85	2		28.28	39.592	Cu
Abdomen				42	85	6		13.19	18.466	
Flu 1				37	85	7		15.58	21.812	
				31	85	10		18.18	25.452	
				27	85	13		23.32	32.648	
				22	85	19		31.22	43.708	
				19	85	26		44.41	62.174	
				15	85	34		52.38	73.332	
Flu 2			2	48	85	4		9.08	12.712	Cu

DOSE ASSESSMENT

Percent increases dose of each Field size (cm)

Field size (cm)	(Patient entrance surface air kerma) Copper filter entrance air kerma (μGy/s)			Dose increases % (1/2) (Flu1, Flu 2)	Dose increases % (1/3) (Flu1, Flu 3)	Dose increases % (2/3) (Flu2, Flu 3)
	FLU2	FLU2	FLU3			
48	35.57	207.4	237.2	82.85	85.00	12.56
42	53.18	248	284	78.56	81.27	12.68
37	63.46	268	306.1	76.32	79.27	12.45
31	58.83	303.7	346.3	80.63	83.01	12.30
27	70.42	346.6	399.9	79.68	82.39	13.33
22	88.78	439.2	483.6	79.79	81.64	9.18
19	104.6	491.8	564.5	78.73	81.47	12.88
15	128.9	623	685.3	79.31	81.19	9.09

AUTOMATIC BRIGHTNESS CONTROL TEST

FID 100 cm

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu)	Field size (cm)	Dose rate **(mGy/s)**	kV	mA	Phantom
Flu 2	Normal mode	**15**	**0.4+1.0 mmAl**	**42**	**0.869**	**77**	**13.5**	**3mmCu**
		15	**0.4+1.0 mmAl**	**42**	**0.490**	**71**	**10.1**	**2 mm Cu**
		15	**0.4+1.0 mmAl**	**42**	**2.677**	**63**	**5.1**	**1 mm Cu**

***Only one mode and field size is checked (about 20 cm)**

MAXIMUM DOSERATE ASSESSMENT

SID 100 cm 3.2 mmAl Chamber to focus distance 60 cm

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu)	Field size (cm)	kV	mA	Doserate (mGy/s)	Phantom
Flu 1	low	15/s	2	48	96.0	8.2	0.569	Pb 1.5
				42	98.0	8.3	0.535	
				37	101.0	8.5	0.602	
				31	107.0	8.9	0.746	
				27	115.0	9.4	0.974	
				22	120.0	9.1	1.066	
				19	120.0	9.1	1.110	
				15	120.0	9.1	1.110	
Flu 2	normal	15/s	2	48	97.0	12.0	1.563	Pb 1.5
				42	101.0	11.5	1.622	
				37	107.0	11.0	1.698	
				31	120.0	10.1	2.088	
				27	120.0	10.1	2.158	
				22	120.0	10.1	2.185	
				19	120.0	10.1	2.202	
				15	120.0	10.1	2.203	

MAXIMUM DOSERATE ASSESSMENT

SID 100 cm 3.2 mmAl Chamber to focus distance 60 cm

Mode	Submode/ Image quality	Pulse rate (pulses/s)	Automatic added filtration (mmCu)	Field size (cm)	kV	mA	Doserate (mGy/s)	Phantom
Flu 3	normal	15/s	2	48	106.0	11.0	1.788	Pb 1.5
				42	113.0	10.6	1.908	
				37	120.0	10.1	2.125	
				31	120.0	10.1	2.148	
				27	120.0	10.1	2.165	
				22	120.0	10.1	2.195	
				19	120.0	10.3	2.172	
				15	120.0	10.3	2.207	
Flu 1	normal	15/s	2	48	120	8.8	1.066	Pb 2
				42	120	8.9	1.069	
				37	120	9.0	1.092	
				31	120	9.0	1.107	
				27	120	9.1	1.113	
				22	120	9.1	1.108	
				19	120	9.1	1.126	
				15	120	9.1	-	

**Measure dose rate for all modes and FOVs, dosimeter on the table and table at the lowest position Absorber: 2 mm of lead on the image intensifier (or equivalent attenuation with a folded lead apron)

FIELD SIZE ASSESSMENT

SID 100 cm, Focus to Table 52 cm, Table to FD 48 cm

Mode	Submode/ Image quality	Field size (cm)	Horizontal size (cm) A-C position	Vertical size (cm)	Measure	% dev
Flu 2	15/s	48	37.3	28.9	47.2	1.67
		42	28.8	28.0	40.17	4.4
		37	25.5	25.4	35.99	2.7
		31	21.6	22.5	31.19	0.6
		27	18.60	18.50	26.23	2.8
		22	15.40	15.30	21.7	1.32
		19	13.10	13.00	18.45	2.86
		15	10.90	10.90	15.41	2.7

*** make measurements of field size for all the available magnifications**

IMAGE QUALITY ASSESSMENT

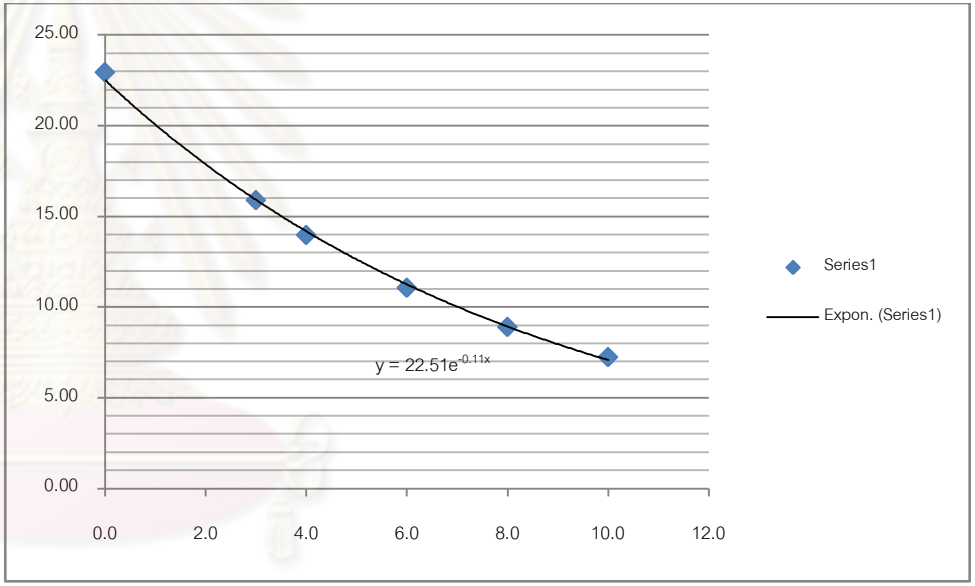
Resolution should be assesed in the usual illumination conditions and from the operator's position. Leeds Test placed on Image flat-panel detector entrance surface with grid. High contrast resolution should have strip pattern at about 45° in respect to raster lines (no absorbers; kv: 40-60).All modes (fluoroscopy and image acquisition) and image qualities and FOVs.

Monitor Focus-Flat-panel detector 100 cm

Mode	Submode/ Image quality	Focus F/L	Automatic added filtration	Field size	kV	mA	(Group)	Live image	low contrast % contrast
								High contrast resolution , lp/mm	
Flu	Flu 2	L	0.0	48	61.0	3.3	6.5	0.80	0.032
FD 4.8				42	61.0	3.9	6.5	1.0	0.039
				37	62.0	4.1	9.0	1.3	0.032
				31	62.0	4.6	9.0	1.3	0.032
				27	63.0	5.1	11.0	1.6	0.039
				22	65.0	5.8	14.0	2.2	0.035
				19	65.0	6.1	15.0	2.5	0.039
				15	66.0	6.8	15.0	2.5	
Flu	Flu 2	S	0.0	48	85.0	3.0	5.0	0.8	0.052
FD 4.8				42	85.0	2.0	7.0	1.00	0.022
				37	85.0	2.0	9.0	1.25	0.017
				31	85.0	2.0	12.0	1.80	0.017
				27	85.0	3.0	14.0	2.24	0.017
				22	85.0	4.0	14.0	2.24	0.017
				19	85.0	4.0	14.0	2.24	0.017
				15	85.0	4.0	16.0	2.8	

HALF VALUE LAYER ASSESSMENT

Al attenuator (mm)	Submode/ Image quality	Doserate (mGy/min)	HVL (mmAl)
0.0		22.93	
3		15.88	
4		13.96	
6		11.05	
8		8.89	6.20
10		7.23	



Make measurement in fluoroscopy mode; add attenuator (copper sheets) on FD to drive kV to 80 kV

TABLE ATTENUATION

SID 100 cm, SPD 52.5 cm 25 FS add 2 mmCu

Mode	Submode/Image Quality	Doserate (mGy/min)	Table attenuation %	Absorber
C-arm at 0°	Normal	49.5	5.9	2 mmCu
C-arm at 90°	Normal	52.4		

Measurement of dose rate in fluoroscopy for the same mode and field size

APPENDIX E

COMPLEXITY INDEX IN TOCE PROCEDURES

Pt No.	1	2	3	4	5	6	7	8	9	10
Date (D/M/Y)	6/5/2009	6/5/2009	7/5/2009	12/5/2009	13/5/2009	14/5/2009	14/5/2009	19/5/2009	19/5/2009	20/5/2009
Age : M/F	M/67	M/63	F/54	M/79	M/53	M/49	M/55	M/53	M/60	M/40
Wt(kg) : Ht(cm)	74/169	70/170	66/151	72/166	43/156	68/168	43/160	69/168	75/160	78/168
Cooperation/Breath hold/Movement (y/n)	no	no	no	no	no	no	no	no	no	no
Disease TYPE A-E	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC
Procedure Elective/Emergency	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective
No. of tumor						1	1	10		>10
No. of bleeder						0	0	0		0
Tumor Diameter(cm)						8 cm	6 cm	1-7 cm		1-8 cm
Hepatic segment(s) segment 1 to 8						seg 7,8	seg 5,6,7,8	both		both lobe
Angulations <45/45-90/>90	45-90	45-90	45-90	45-90	45-90	>90	>90	>90	45-90	<90
Branching										
0:no side branch 1: bifurcation 2 :trifurcation	2	2	2	2	2	2	1	2	2	2
Tortuosity										
mild 0-1 curves moderate 2-3 severe : more than 3	mild	mild	mild	mild	mild	mild	moderate	mild	mild	mild
Invasion (0-3)										
0:normal 1:2nd tributary 2:1st tributary 3: main	0	0	0	0	0	1	1		0	1
Portal vein : AP shunt (y/n)	no	no	no	no	no	no	yes	no	no	no AV shunt
No of catheter used	1	1	1	1	1	1	1	3	3	2
Conventional/Micro	micro4	micro4	micro4	micro4	micro4	no	no	micro	micro	conven
No of guide wire used	1	1	1	1	1	1	1	1	1	1
Embolic material	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam		Gelfoam
Anticancer drug	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU
Complication during procedure	no	no	no	no	no	no	no	no	no	no
Operators Experience in interventional, yrs.	3	3	3	15	3	3	3	23	3	1

COMPLEXITY INDEX IN TOCE PROCEDURES

Pt No.	11	12	13	14	15	16	17	18	19	20
Date (D/M/Y)	20/5/2009	21/5/2009	21/5/2009	22/5/2009	25/5/2009	25/5/2009	26/5/2009	26/5/2009	27/5/2009	29/5/2009
Age : M/F	M/68	M/47	M/68	M/59	M/58	F/63	M/54	M/56	M/53	M/62
Wt(kg) : Ht(cm)	49/ 152	69/153	46.3/165	67/170	56/170	81.2/153.5	92/180	70/182	65/167	61/150
Cooperation/Breath hold/Movement (y/n)	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
Disease TYPE A-E	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC
Procedure Elective/Emergency	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective
No. of tumor	2			multiple	1	1	1	1	3	1
No. of bleeder	no			0	no	no	no	no	no	no
Tumor Diameter(cm)	1.5 cm			2 cm	1 cm		1 cm		1.5-4 cm.	2 cm
Hepatic segment(s) segment 1 to 8	4			8(2,3)	LL	6	5		6,8	2
Angulations <45/45-90/>90		45-90	45-90	45-90	>90	45-90	45-90	45-90	45-90	45-90
Branching										
0:no side branch 1: bifurcation 2 :trifurcation	1	2	2	2	1	2	1	1	1	2
Tortuosity										
mild 0-1 curves moderate 2-3 severe : more than 3		mild	mild	mild	mild	mild	mild	mild	moderate	severe
Invasion (0-3)										
0:normal 1:2nd tributary 2:1st tributary 3: main	0	0	0	0	0	0	0	0	0	0
Portal vein : AP shunt (y/n)	no	no	no	no	no	no	no	no	no	no
No of catheter used	2	2	1	2	2	1	1	1	2	3
Conventional/Micro	micro2	micro2	micro4	micro	micro	micro	micro	micro	micro	micro
No of guide wire used	2	2	1	1	1	1	1	1	1	2
Embolic material	no	no	Gelfoam	no	no	no	no	Gelfoam	no	Gelfoam
Anticancer drug	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU
Complication during procedure	no	no	no	no	no	no	no	no	no	no
Operators Experience in interventional, yrs.	3	3	3	3	3	3	3	15	3	3

COMPLEXITY INDEX IN TOCE PROCEDURES

Pt No.	21	22	23	24	25	26	27	28	29	30
Date (D/M/Y)	29/5/2009	1/6/2009	8/6/2009	9/6/2009	10/6/2009	6/8/2009	14/8/2009	14/8/2009	17/8/2009	20/8/2009
Age : M/F	M/70	M/49	M/68	M/59	M/65	M/51	F/59	F/66	M/54	M/78
Wt(kg) : Ht(cm)	37/156	41/173	87/173	74/165	61.6/162	65/165	58/152	59.9/163	65/170	61/170
Cooperation/Breath hold/Movement (y/n)										
Disease TYPE A-E	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC
Procedure Elective/Emergency	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective
No. of tumor		>10	2	2	1	multiple	1	1	1	1
No. of bleeder		no	no	no	no	no	no	no	no	no
Tumor Diameter(cm)		multiple	1 cm	1.5 cm	1.5 cm	multiple		13X20 mm		10.3x10.5 cm
Hepatic segment(s) segment 1 to 8		2,8	6,7	7,8	4 b	RL	2	5,8	LL	6,7
Angulations <45/45-90/>90	45-90	45-90	45-90	45-90	45-90	>90	45-90	45-90	45-90	45-90
Branching										
0:no side branch 1: bifurcation 2 :trifurcation	1	1	1	1	2	1	2	1	1	2
Tortuosity										
mild 0-1 curves moderate 2-3 severe : more than 3	mild	mild	mild	moderate	severe	mild	severe	severe	mild	moderate
Invasion (0-3)										
0:normal 1:2nd tributary 2:1st tributary 3: main	0	0	0	0	0	no	1	1	0	2
Portal vein : AP shunt (y/n)	no	no	no	y	y	no	no	no	no	y
No of catheter used	1	3	1	2	2	2	1	1	1	1
Conventional/Micro	no	micro	no	no	micro	micro	micro	micro	micro	micro
No of guide wire used	1	2	1	1	1	1	1	1	1	1
Embolic material	Gelfoam	Gelfoam	Gelfoam	no	Gelfoam	no	Gelfoam	Gelfoam	Gelfoam	Gelfoam
Anticancer drug	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU
Complication during procedure	no	no	no	no	no	no	no	no	no	no
Operators Experience in interventional, yrs.	3	3	3	3	3	3	3	3	3	3

COMPLEXITY INDEX IN TOCE PROCEDURES

Pt No.	31	32	33	34	35	36	37	38	39	40
Date (D/M/Y)	20/8/2009	20/8/2009	21/8/2009	24/8/2009	24/8/2008	12/10/2009	7/8/2009	10/9/2009	14/9/2009	15/9/2009
Age : M/F	M/53	F/72	M/52	M/52	M/54	F/66	M/78	M/66	M/70	M/65
Wt(kg) : Ht(cm)	79/180	57/145	53/156	44.5/165	73/168	51/150	53/170	70/158	70/174	72/175
Cooperation/Breath hold/Movement (y/n)									y	
Disease TYPE A-E	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC
Procedure Elective/Emergency	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective
No. of tumor	1	5	1	1	1		2	1	3	
No. of bleeder	no	no	2 feeder	1 fedder	2 feeder	no	no		no	no
Tumor Diameter(cm)		1-5 cm	14.6x11 cm	8x13.5x6.5	10.4x9.6 cm		3,2.5 cm		8.9, 3.9 cm	
Hepatic segment(s) segment 1 to 8	6	2,4,5,6	7,8	1,2,R 3	6,7		S 5,S 8	7	5,8	
Angulations <45/45-90/>90	45-90	45-90	45-90	45-90	45-90	45-90	>90	45-90	45-90	45-90
Branching										
0:no side branch 1: bifurcation 2 :trifurcation	1	2	1	2	2,1	1	2	2	1	1
Tortuosity										
mild 0-1 curves moderate 2-3 severe : more than 3	mild	moderate	moderate	severe	mild,mode	mild	severe	severe	severe	mild
Invasion (0-3)										
0:normal 1:2nd tributary 2:1st tributary 3: main	normal	tributary	normal	normal	normal	normal	normal	normal	normal	normal
Portal vein : AP shunt (y/n)	no	no	no	no	no	no	yes	no	no	no
No of catheter used	1	2	2	3	2	2	2	1	1	1
Conventional/Micro	micro	micro 2	micro	micro	micro	micro	micro	micro	micro	no
No of guide wire used	1	2	1	1	1	1	1	1	1	1
Embolic material	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam
Anticancer drug	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU
Complication during procedure	pain	pain	pain	no	no	no	no	no	no	no
Operators Experience in interventional, yrs.	3	3	3	3	3	3	3	3	3	1

COMPLEXITY INDEX IN TOCE PROCEDURES

Pt No.	41	42	43	44	45	46	47	48	49	50
Date (D/M/Y)	20/8/2009	20/8/2009	21/8/2009	24/8/2009	24/8/2008	12/10/2009	7/8/2009	10/9/2009	14/9/2009	15/9/2009
Age : M/F	M/53	M/72	M/52	M/52	M/54	M/66	M/78	M/66	M/70	M/65
Wt(kg) : Ht(cm)	79/180	57/145	53/156	44.5/165	73/168	51/150	53/170	70/158	70/174	72/175
Cooperation/Breath hold/Movement (y/n)										
Disease TYPE A-E	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC
Procedure Elective/Emergency	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective
No. of tumor	1	1	1		1	2				
No. of bleeder	no	no	no	no	no	no	no	no	no	no
Tumor Diameter(cm)	1.5 cm	1.4 cm	12X10 cm		1 cm	1-2 cm				
Hepatic segment(s) segment 1 to 8	4	S4 lt lobe			4	5				
Angulations <45/45-90/>90	45-90	45-90		45-90	45-90	45-90	45-90	45-90	45-90	45-90
Branching										
0:no side branch 1: bifurcation 2 :trifurcation	1	1	1	1	1	1	1	1	1	1
Tortuosity										
mild 0-1 curves moderate 2-3 severe : more than 3	moderate	moderate	moderate	mild	mild	mild	mild	mild	mild	mild
Invasion (0-3)										
0:normal 1:2nd tributary 2:1st tributary 3: main										
Portal vein : AP shunt (y/n)	no	no	no	no	no	no	no	no	no	no
No of catheter used	2	2	1	1	1	1	1	1	1	1
Conventional/Micro	micro	no	no	no	no	no	no	micro	no	micro
No of guide wire used	1	1	1	1	1	1	1	1	1	1
Embolic material	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam	Gelfoam
Anticancer drug	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU
Complication during procedure	no	no	no	no	no	no	no	no	no	no
Operators Experience in interventional, yrs.	3	15	3	3	3	1	1	3	1	1

COMPLEXITY INDEX IN TOCE PROCEDURES

Pt No.	51	52	53	54	55	56	57	58	59	60
Date (D/M/Y)	6/11/2009	6/11/2009	6/11/2009	10/11/2009	11/11/2009	12/11/2009	12/11/2009	13/11/2009	16/11/2009	17/11/2009
Age : M/F	M/38	M/54	M/38	F/76	F/56	M/61	M/55	M/78	M/46	M/76
Wt(kg) : Ht(cm)	55/167	62/165	55/167	45/145	64/167	64/177	52/169	55/158	56.7/170	61/164
Cooperation/Breath hold/Movement (y/n)									no	no
Disease TYPE A-E	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC
Procedure Elective/Emergency	Elective	Elective	Elective	Elective	Elective	Elective/DIAG	Elective	Elective	Elective	Elective
No. of tumor				3	2	0	1	1	1	กระจาย
No. of bleeder				no	no	no	no	no	no	no
Tumor Diameter(cm)				0.7,1.8,1.7	1,2.5 cm	no	8.5x9.2 cm	10 cm	11.8	กระจาย
Hepatic segment(s) segment 1 to 8				7	8	no	7	Rt. Lobe	4	rt lobe
Angulations <45/45-90/>90	45-90	45-90	45-90	90		45-90	45-90	<45,45-90	45-90	>90
Branching 0:no side branch 1: bifurcation 2 :trifurcation	1	2	2	2	1	1	1	2	1	2
Tortuosity mild 0-1 curves moderate 2-3 severe : more than 3	moderate	moderate	moderate	severe	moderate	mild	severe	severe	moderate	severe
Invasion (0-3) 0:normal 1:2nd tributary 2:1st tributary 3: main										
Portal vein : AP shunt (y/n)	no	no	no	no	no	no	no	no	no	
No of catheter used	1	1	1	2	1	1	1	2	1	3
Conventional/Micro	no	micro	micro	micro 2	micro	no	no	micro	no	micro
No of guide wire used	1	1	1	1	1	1	1	1	1	1
Embolic material	Gelfoam	Gelfoam	Gelfoam	no	Gelfoam	no	Gelfoam	Gelfoam	Gelfoam	Gelfoam
Anticancer drug	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	no	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU
Complication during procedure	no		no	no	no	no	no	no	no	no
Operators Experience in interventional, yrs.	1	3	3	3	3	3	3	15	3	15

COMPLEXITY INDEX IN TOCE PROCEDURES

Pt No.	61	62	63	64	65	66	67	68	69
Date (D/M/Y)	17/11/2009	17/11/2009	18/11/2009	19/11/2009	20/11/2009	23/11/2009	23/11/2009	24/11/2009	26/11/2009
Age : M/F	F/71	M/56	M/82	F/79	F/59	M/57	M/40	F/36	M/69
Wt(kg) : Ht(cm)	57/145	48/167.5	52/170	56/165	65/150	53.2/160	120/178	43/156	56/156
Cooperation/Breath hold/Movement (y/n)									no
Disease TYPE A-E	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC	HCC
Procedure Elective/Emergency	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective	Elective
No. of tumor	1	multiple	2	2	4	multiple			multiple
No. of bleeder	no	no	no	no	no	no	no	no	no
Tumor Diameter(cm)	1	1-2 cm	8 cm	2,3 cm	1,2,7,9 cm	6,3 cm			
Hepatic segment(s) segment 1 to 8	7	RL	LL,ML	3,7	5,8	6			Rt lobe
Angulations <45/45-90/>90	45-90	45-90	45-90	45-90		>90	45-90	45-90	
Branching									
0:no side branch 1: bifurcation 2 :trifurcation	1	2	1	2	2	2	2	2	1(Rt lobe)
Tortuosity									
mild 0-1 curves moderate 2-3 severe : more than 3	moderate	moderate	mild	moderate	mild	severe	moderate	moderate	moderate
Invasion (0-3)									
0:normal 1:2nd tributary 2:1st tributary 3: main									
Portal vein : AP shunt (y/n)	no	no		no	no	no	no	yes	no
No of catheter used	1	1	1	1	1	3	1	2	1
Conventional/Micro	no	micro	micro	micro	micro	micro	no	micro	micro
No of guide wire used	1	1	1	1	1	1	1	1	1
Embolic material	no	Gelfoam	Gelfoam	no	no	PVA	no	Gelfoam	Gelfoam
Anticancer drug	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU	MMC,5FU
Complication during procedure	no	no	no	no	no	no	no	no	no
Operators Experience in interventional, yrs.	1	3	1	3	1	3	3	15	1

VITAE

NAME : Miss.Pimnuttha Sitthiphan

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INSTITUTIONS ATTENDED : Ramkhamhaeng University, 2005
Bachelor of Science
(Radiological Technology)

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Master of Science
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POSITION HELD & OFFICE :

- Radiological Technologist of Department of Radiology, Thonburi Hospital for 6 years
- Radiological Technologist and Specialist Interventional Radiology, Phyathai State of The Art Imaging Center, Phyathai 2 Hospital for 3 years**.**

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Phyathai Hospital's Grant had been supported for Master Degree of Science (Medical Imaging), Department of Radiology, Faculty of Medicine, and Chulalongkorn University.