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The study of local diagnostic reference levels at unit of vascular and interventional radiology, King Chulalongkorn memorial hospital

Kornkamol Prajamchuea
Faculty of Medicine

THE STUDY OF LOCAL DIAGNOSTIC REFERENCE LEVELS AT UNIT OF VASCULAR AND INTERVENTIONAL RADIOLOGY, KING CHULALONGKORN MEMORIAL HOSPITAL

Miss Kornkamol Prajamchuea

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การศึกษาระดับปริมาณรังสีอ้างอิงที่ผู้ป่วยได้รับระดับแผนกที่หน่วยงานรังสีวิทยาหลอดเลือด และร่วมรักษา โรงพยาบาลจุฬาลงกรณ์ สภากาชาดไทย

น.ส.กรกมล ประจำเชื้อ

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By	Miss Kornkamol Prajamchuea
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Thesis Advisor	Associate Professor ANCHALI KRISANACHINDA, Ph.D.

Accepted by the FACULTY OF MEDICINE, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

-- Dean of the FACULTY OF MEDICINE

(Professor SUTTIPONG WACHARASINDHU, M.D.)

THESIS COMMITTEE

-- Chairman

(Assistant Professor KITIWAT KHAMWAN, Ph.D.)

-- Thesis Advisor

(Associate Professor ANCHALI KRISANACHINDA, Ph.D.)

-- External Examiner

(Professor Kosuke Matsubara, Ph.D.)

กรกมล ประจำเชื้อ : การศึกษาระดับปริมาณรังสีอ้างอิงที่ผู้ป่วยได้รับระดับแผนกที่หน่วยงานรังสีวิทยาหลอดเลือด และ ร่วมรักษา โรงพยาบาลจุฬาลงกรณ์ สภากาชาดไทย. (THE STUDY OF LOCAL DIAGNOSTIC REFERENCE LEVELS AT UNIT OF VASCULAR AND INTERVENTIONAL RADIOLOGY, KING CHULALONGKORN MEMORIAL HOSPITAL) อ.ที่ปรึกษาหลัก : รศ. ดร.อัญชลี กฤษณจินดา

หัตถการทางด้านรังสีวิทยาหลอดเลือดและร่วมรักษาเป็นหัตถการผ่าตัดขนาดเล็กโดยใช้เครื่องมือทางด้านรังสีร่วมรักษาที่ทำให้ผู้ป่วยและบุคลากรการแพทย์ได้รับรังสีปริมาณสูง คณะกรรมาธิการระหว่างประเทศเกี่ยวกับการป้องกันอันตรายจากรังสีได้กำหนดระดับปริมาณรังสีอ้างอิงในปี ค.ศ. 2017 ที่ตำแหน่งเปอร์เซ็นไทล์ 75 ของค่ามัธยฐานของข้อมูลตัวอย่างผู้ป่วยที่มีน้ำหนักอยู่ในเกณฑ์มาตรฐาน เพื่อเป็นเครื่องมือที่เพิ่มประสิทธิภาพในการป้องกันอันตรายจากรังสีและใช้ปริมาณรังสีทางการแพทย์อย่างเหมาะสมสำหรับหัตถการวินิจฉัยและร่วมรักษา วัตถุประสงค์ของการศึกษา เพื่อสร้างระดับปริมาณรังสีอ้างอิงสำหรับผู้ป่วยได้รับระดับแผนกของผู้ป่วยชาวไทยที่มีน้ำหนักอยู่ในเกณฑ์มาตรฐาน ระหว่างการทำหัตถการด้านรังสีวิทยาหลอดเลือดและร่วมรักษา

ระดับปริมาณรังสีอ้างอิงที่ผู้ป่วยได้รับระดับแผนกของผู้ป่วยชาวไทยที่มีน้ำหนักอยู่ในเกณฑ์ (45-75 กก. สำหรับผู้หญิงและ 50-80 กก.สำหรับผู้ชาย) ของหัตถการด้านระบบประสาทและสมอง 3 หัตถการและหัตถการส่วนลำตัว 9 หัตถการในระบบจัดเก็บรูปภาพทางการแพทย์และโปรแกรมตรวจสอบปริมาณรังสีถูกนำมาวิเคราะห์โดยใช้สถิติเชิงพรรณนาด้วยโปรแกรม SPSS เวอร์ชัน 22 ค่ามัธยฐานของหัตถการด้านรังสีวิทยาหลอดเลือดและร่วมรักษาในการศึกษานี้จะถูกนำไปเปรียบเทียบกับระดับปริมาณรังสีอ้างอิงของผู้ป่วยระดับประเทศ

ข้อมูลผู้ป่วยของหัตถการด้านระบบประสาทและสมอง 87 คนและหัตถการส่วนลำตัว 398 คน รวมทั้งหมด 485 คนถูกรวบรวมในระหว่างเดือน มกราคม ถึง เดือน มิถุนายน พ.ศ. 2563 โดยมีผลการศึกษา ดังนี้ ค่าแคพมิเตอร์ที่ตำแหน่งมัธยฐานและเปอร์เซนไทล์ที่ 75 (ระดับปริมาณรังสีอ้างอิง) ของการวินิจฉัยโรคหลอดเลือดสมอง คือ 49 และ 61 เกรย์ตร.ซม. การอุดเส้นเลือดโรคหลอดเลือดสมองโป่งพองในกะโหลกศีรษะ คือ121 และ 144 เกรย์ตร.ซม. การอุดเส้นเลือดโรคหลอดเลือดสมองผิดปกติเอวีเอ็ม คือ 157 และ 224 เกรย์ตร.ซม. การให้ยาเคมีบำบัดทางเส้นเลือดแดงที่ตับโดยใช้ภาพจากเครื่องเอกซเรย์คอมพิวเตอร์ คือ 287 และ 459 เกรย์ตร.ซม. การให้ยาเคมีบำบัดทางเส้นเลือดแดงที่ตับโดยใช้ภาพจากลำรังสีรูปกรวย คือ 238 และ 397 เกรย์ตร.ซม. การใส่สายสวนภายในหลอดเลือดดำส่วนกลาง คือ 0.7 และ 1 เกรย์ตร.ซม. การใส่สายสวนภายในหลอดเลือดดำสำหรับฟอกเลือดชนิดถาวร 1 และ 4 เกรย์ตร.ซม. การใส่สายระบายผ่านทางผิวหนัง 2 และ 4 เกรย์ตร.ซม. การใส่สายระบายน้ำดี 6 และ 14 เกรย์ตร.ซม. การวินิจฉัยโรคหลอดเลือดแดงส่วนปลาย 4 และ 18 เกรย์ตร.ซม. การขยายหลอดเลือดโรคหลอดเลือดแดงส่วนปลาย 7 และ 16 เกรย์ตร.ซม. การตัดชิ้นเนื้อส่งตรวจโดยใช้ภาพจากลำรังสีรูปกรวย 12 และ 17 เกรย์ตร.ซม. ตามลำดับ ความหนาของลำตัว, ดัชนีความยาก, เครื่องมือทางด้านรังสีร่วมรักษา, อุปกรณ์ทางด้านรังสีร่วมรักษา, เทคนิคปริมาณรังสี, ทักษะและการตัดสินใจของรังสีแพทย์มีผลต่อปริมาณรังสีที่ผู้ป่วยได้รับ

ปริมาณรังสีที่ผู้ป่วยได้รับของหัตถการร่วมรักษามากกว่าหัตถการวินิจฉัย ดังนั้น ปริมาณรังสีที่ผู้ป่วยได้รับในระหว่างการทำหัตถการทางด้านรังสีวิทยาหลอดเลือดและร่วมรักษาควรมีการควบคุมในปริมาณที่เหมาะสมและทบทวนระดับปริมารรังสีอ้างอิงทุกปี เพื่อประเมินเทคนิคปริมาณรังสี ลดความเสี่ยงทางรังสีที่ผู้ป่วยได้รับและลดปริมาณรังสีกระเจิงที่บุคลากรการแพทย์ได้รับ การศึกษาระดับปริมาณรังสีอ้างอิงที่ผู้ป่วยได้รับระดับแผนกเป็นการศึกษาในปี พ.ศ. 2563 ซึ่งระดับปริมาณรังสีอ้างอิงที่ผู้ป่วยได้รับของประเทศไทยจัดตั้งขึ้นในปี พ.ศ. 2564 รายงานการศึกษาระดับปริมาณรังสีอ้างอิงที่ผู้ป่วยได้รับระดับแผนกนี้จะเป็นฐานข้อมูลที่มีประโยชน์ในการจัดตั้งระดับปริมาณรังสีอ้างอิงที่ผู้ป่วยได้รับของประเทศไทย

สาขาวิชา	ฟิสิกส์การแพทย์	ลายมือชื่อนิสิต	....
ปีการศึกษา	2563	ลายมือชื่อ อ.ที่ปรึกษาหลัก	....

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Kornkamol Prajamchuea : THE STUDY OF LOCAL DIAGNOSTIC REFERENCE LEVELS AT UNIT OF VASCULAR AND INTERVENTIONAL RADIOLOGY, KING CHULALONGKORN MEMORIAL HOSPITAL. Advisor: Assoc. Prof. ANCHALI KRISANACHINDA, Ph.D.

Interventional Radiology (IR) procedures are minimally invasive surgery using angiographic equipment which the patients and staffs may receive high radiation dose. DRLs, based on 75th percentile of the median dose for a sample of standard sized of patients, are an effective tool for optimization of protection in the medical exposure of patients for diagnostic and interventional procedures (ICRP Publication 135, 2017). The objective of this study is to establish the local DRLs distribution of patient radiation dose and related parameters in interventional radiology procedures in standard-sized of Thai patients.

Local DRLs of radiation dose and related parameters of patients (45-75kg for female, and 50-80kg for male) who underwent 3 Neuro-interventional and 9 body interventional procedures were established by retrieving the patient data from PACS and Radimetrics. The data analysis used descriptive statistics via SPSS version 22. The median value of interventional radiology procedures in this study were compared to National DRLs.

The patient data of 485 cases, neuro-intervention 87 cases and body intervention 398 cases, were reviewed and collected between January 2019 and June 2020. The results show that: the median of KAP value and 75th percentile (DRLs) of Cerebral angiogram were 49 and 61 Gy.cm^2, Embolization of intracranial aneurysm were 121 and 144 Gy.cm^2, Embolization of brain AVM were 157 and 224 Gy.cm^2, CT-guided TACE were 287 and 459 Gy.cm^2, CBCT-guided TACE were 238 and 397 Gy.cm^2, PICC line were 0.7 and 1 Gy.cm^2, Perm cath were 1 and 4 Gy.cm^2, PCD were 2 and 4 Gy.cm^2, PTBD were 6 and 14 Gy.cm^2, Peripheral angiogram were 4 and 18 Gy.cm^2, Peripheral angioplasty were 7 and 16 Gy.cm^2, CBCT-guided Biopsy were 12 and 17 Gy.cm^2, respectively. The thickness of the body part, the complexity index, the angiographic equipment, the angiographic materials, the exposure techniques and the interventional radiologists' skill and decision influence the patient radiation dose.

As the patient radiation doses in the therapeutic procedure are always higher than the diagnostic procedures, the DRLs of interventional radiology procedures should be optimized and reviewed DRLs annually. The exposure techniques to decrease the risk of patient radiation dose and reducing scatter radiation to all staffs should be reviewed. The Local DRLs of interventional radiology procedures is established in 2020 while Thailand DRLs is established in 2021. The Local DRLs report is useful in providing a guidance on National DRLs database.

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Academic Year: 2020		Advisor's Signature ....

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Kornkamol Prajamchuea

TABLE OF CONTENTS

Page

ABSTRACT (THAI) iii

ABSTRACT (ENGLISH) iv

ACKNOWLEDGEMENTS v

TABLE OF CONTENTS vi

LIST OF TABLES ix

LIST OF FIGURES xi

LIST OF ABBREVIATIONS xii

CHAPTER I INTRODUCTION 1

1.1 Background and rationale 1

1.2 Research objective 2

CHAPTER II REVIEW OF RELATED LITERATURE 3

2.1 Theory 3

2.1.1 Interventional Radiology 3

2.1.2 Digital Subtraction Angiography (DSA) system 4

2.1.3 Radiation quantity 5

2.1.4 ICRP Publication 135 Recommendation of Diagnostic Reference Levels in Medical Imaging 6

2.1.5 Diagnostic Reference Levels 6

2.2 Review of related literature 7

CHAPTER III RESEARCH METHODOLOGY 10

3.1 Research design 10

3.2 Conceptual framework 10

3.3 Research design model 11

3.4 Research question.....11
3.5 Research objective.....11
3.6 Sample.....12
3.6.1 Target population.....12
3.6.2 Sample population.....12
3.7 Eligible criteria.....12
3.7.1 Inclusion criteria.....12
3.7.2 Exclusion criteria.....13
3.8 Sample size determination.....13
3.9 Materials.....13
3.9.1 Quality Control of the equipment in the study using IAEA TRS 457 and AAPM Report no.58.....13
3.9.2 Research equipment.....16
3.10 Methods.....18
3.11 Variables measurement.....19
3.11.1 Independent variables.....19
3.11.2 Dependent variables.....19
3.12 Statistical analysis.....20
3.13 Data analysis.....20
3.14 Outcomes.....20
3.15 Expected benefits.....20
3.16 Limitation.....21
3.17 Ethical consideration.....21
CHAPTER IV RESULTS.....22
4.1 Quality control of the angiographic equipment.....22
4.2 The patient information.....22
4.3 The exposure and related parameters.....26
4.4 Local Diagnostic Reference Levels (LDRLs) distribution.....30

4.5 Comparison of LDRLs to NDRLs....33
CHAPTER V DISCUSSION AND CONCLUSION....35
5.1 LDRLs of the interventional radiology procedures....35
5.2 Comparison of LDRLs to NDRLs....37
5.3 The factors affected the patient radiation dose during interventional radiology procedures....37
5.4 Conclusion....39
APPENDIX A CASE RECORD FORM....42
APPENDIX B EQUIPMENT PERFORMANCE FOR ANGIOGRAPHY SYSTEM....44
REFERENCES....69
VITA....72

LIST OF TABLES

Page

Table 2. 1 Angiographic Local DRLs – Abdominal interventional radiology procedure . 7
Table 2. 2 Comparison of 75th percentile DRLs value of this study and preliminary DRLs proposed by IAEA, DIMOND III and SENTINEL 8
Table 4. 1 Patient information of the Neuro-interventional Procedures 23
Table 4. 2 Patient information of the Body interventional Procedures 25
Table 4. 3 The parameters related to exposure of Neuro-interventional procedures.. 26
Table 4. 4 The parameters related the exposure of the Body interventional procedures.. 28
Table 4. 5 Median of fluoroscopy time (min), 25th percentile, 50th percentile (median), 75th percentile (DRLs) of KAP (Gy.cm^2) values, median No. of images and Effective dose (mSv) of interventional radiology procedures .. 31
Table 4. 6 Comparing 50th percentile in this study to Erskine's study, Schegerer's study, Japan DRLs 2020 and Thailand DRLs 33
Table A. 1 Data collection for body interventional procedure 42
Table A. 2 Data collection for neuro-interventional procedure 43
Table B. 1. 1 Dose assessment of Canon (Toshiba) Infinix 45
Table B. 1. 2 Automatic Brightness Control (ABC) test of Canon (Toshiba) Infinix 46
Table B. 1. 3 Maximum dose rate assessment of Canon (Toshiba) Infinix 46
Table B. 1. 4 Field size assessment of all radiation fields 47
Table B. 1. 5 Table attenuation of Canon (Toshiba) Infinix 47
Table B. 1. 6 Half Value Layer (HVL) of Canon (Toshiba) Infinix 48
Table B .1. 7 Image quality assessment of Canon (Toshiba) Infinix 48
Table B. 2. 1 Dose assessment of Siemens Artis Zee single plane 50
Table B. 2. 2 Automatic Brightness Control (ABC) test of Siemens Artis Zee single plane 51
Table B. 2. 3 Maximum dose rate assessment of Siemens Artis Zee single plane 51

Table B. 2. 4 Field size assessment of all radiation fields 52
Table B. 2. 5 Table attenuation of Siemens Artis Zee single plane 52
Table B. 2. 6 Half Value Layer (HVL) of Siemens Artis Zee single plane 53
Table B. 2. 7 Image quality assessment of Siemens Artis Zee single plane 53
Table B. 3. 1 Dose assessment of plane A and B of Siemens Artis Zee biplane 55
Table B. 3. 2 Automatic Brightness Control (ABC) test of plane A and B of Siemens Artis Zee biplane 56
Table B. 3. 3 Maximum dose rate assessment of plane A and B of Siemens Artis Zee biplane 57
Table B. 3. 4 Field size assessment of all radiation fields 58
Table B. 3. 5 Table attenuation of plane A of Siemens Artis Zee biplane 59
Table B. 3. 6 Half Value Layer (HVL) of plane A and B of Siemens Artis Zee biplane 59
Table B. 3. 7 Image quality assessment of plane A and B of Siemens Artis Zee biplane 60
Table B. 4. 1 Dose assessment of plane A and B of Philips Allura Clarity Xper FD20/15 62
Table B. 4. 2 Automatic Brightness Control (ABC) test of plane A and B of Philips Allura Clarity Xper FD20/15 63
Table B. 4. 3 Maximum dose rate assessment of plane A and B of Philips Allura Clarity Xper FD20/15 64
Table B. 4. 4 Field size assessment of all radiation fields 65
Table B. 4. 5 Table attenuation of plane A of Philips Allura Clarity Xper FD20/15 66
Table B. 4. 6 Half Value Layer (HVL) of plane A and B of Philips Allura Clarity Xper FD20/15 66
Table B. 4. 7 Image quality assessment of plane A and B of Philips Allura Clarity Xper FD20/15 67

LIST OF FIGURES

Page

Figure 2. 1 Peripheral angiographic images, DSA technique (a. a mask image, b. a mask-contrast image, c. a subtracted image, d. an inverse subtracted image) 4
Figure 2. 2 Air KERMA at the interventional reference point and DAP meter, illustrated by Lee MY, Review article in: Progress in Medical Physics 2019 5
Figure 3. 1 Overview of conceptual framework 10
Figure 3. 2 Research design model of the local DRLs distribution 11
Figure 3. 3 Reference dosimeter, a. Solid state dosimeter (XR multi-detector), b. MagicMaX universal multifunction for advanced beam verification and quality assurance for all x-ray imaging modalities 14
Figure 3. 4 Copper plate 14
Figure 3. 5 Collimator/Beam Alignment Test Tool manufactured by RMI model 07-661-7662 15
Figure 3. 6 TOR Leeds test object 15
Figure 3. 7 Acrylic Phantom Material (PMMA slab phantom) 16
Figure 3. 8 Angiographic equipment a. Canon (Toshiba) hybrid angiography CT system model Infinix-i 4D CT, b. Philips biplane fluoroscopy model Allura Clarity Xper FD20/15®, c. Siemens single plane fluoroscopy model Artis zee with PURE®, d. Siemens biplane 17
Figure 4. 1 Minimum, maximum, 25th percentile, 50th percentile (median), 75th percentile (DRLs) values of neuro-interventional procedures 32
Figure 4. 2 Minimum, maximum, 25th percentile, 50th percentile (median), 75th percentile (DRLs) values of body interventional procedures 32

LIST OF ABBREVIATIONS

ABC	Automatic Brightness Control
AD	Achievable Dose
AK	Air KERMA
AVM	Arteriovenous Malformation
CAG	Coronary Angiography
CAK	Cumulative Air KERMA
CBCT	Cone Beam Computed Tomography
cm	Centimeter
cm^2	Centimeter square
CT	Computed Tomography
DAP	Dose Area Product
DRLs	Diagnostic Reference Levels
DSA	Digital Subtraction Angiography
EMR	Electronic Medical Record
EVAR	Endovascular Aortic Repair
g/cm^3	Gram/Centimeter cube
GI	Gastrointestinal
Gy	Gray
$Gy.cm^2$	Gray-centimeter square
HVL	Half Value Layer
IAEA	International Atomic Energy Agency
IBM	International Business Machines
ICRP	International Commission on Radiological Protection
ICRU	International Commission on Radiation Units and Measurements
IGIP	Imaging Guidance Interventional Procedure
IR	Interventional Radiology
IRB	Institutional Review Board
IVC	Inferior Vena Cava
J/kg	Joule/Kilogram
KAP	KERMA-Area Product
Kg	Kilogram
kVp	Kilovoltage Peak

LDRLs	Local Diagnostic Reference Levels
mAs	Milliampere-second
mGy	MilliGray
min	Minute
mm	Millimeter
ms	Millisecond
mSv	MilliSievert
NCRP	National Council on Radiation Protection and Measurements
NDRLs	National Diagnostic Reference Levels
No.	Number
NIR	Neuro-interventional Radiology
NRPB	National Radiological Protection Board
PACS	Picture Archiving and Communication System
PCD	Percutaneous Collection Drainage
PCI	Percutaneous Transluminal Coronary Intervention
Perm	Permanent double lumen
PICC	Peripheral Inserted Central Catheter
PMMA	Polymethylmetha crylate
PTBD	Percutaneous Transhepatic Biliary Drainage
QC	Quality Control
RDRLs	Regional Diagnostic Reference Levels
RMI	Radiological Medica Imaging
s	Second
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
TACE	Trans Arterial Chemo Embolization
TIPS	Transjugular Intrahepatic Portosystemic Shunt
TOR	Routine Test Object
TRS	Technical Reports Series
TTNB	Transthoracic Needle Biopsy

UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
Y	Year

CHAPTER I

INTRODUCTION

1.1 Background and rationale

Diagnostic Reference Levels (DRLs) (1) in medical imaging were introduced in 1990 for diagnostic radiology examinations and defined as a practical tool to optimize the patient radiation dose to the lowest possible exposure, but the image quality is still maintained for the diagnostic and therapeutic procedures. DRLs are a general guideline based on 75^{th} percentile of the median dose for a sample of standard sized of patients. This means the optimization of patient radiation dose should be between 25^{th} percentile and 75^{th} percentile. In order to encourage the optimization of patient radiation dose, a concept of achievable dose (AD) had been introduced by National Radiological Protection Board (NRPB, UK) (2) and recommended by the National Council on Radiation Protection and Measurements (NCRP, USA) (3). The achievable dose is set at the 50^{th} percentile (median) of the survey of dose distribution. The optimization of patient radiation dose should be, in the future, below the achievable dose at 50^{th} percentile level. The DRLs distribution is used for clinical operation and should not be applied directly to individual patient and examination. There are four terms of DRLs, Typical values, Local Diagnostic Reference Levels (LDRLs), National Diagnostic Reference Levels (NDRLs) and Regional Diagnostic Reference Levels (RDRLs) (4). The Local DRLs should be reviewed annually and National DRLs should be reviewed every 5 years.

Interventional radiology (IR) procedure is defined as a medical sub-specialty of radiology utilizing minimally-invasive technique for diagnostic or therapeutic procedures using medical imaging guidance interventional procedure (IGIP) such as fluoroscopy, CT, MRI or ultrasound, to precisely guide medical devices into the internal structures of the body in real time through very small incision. There are two parts of interventional radiology procedures follow the human body such as neuro-intervention and body intervention. The procedures are also separated into two

groups. A group of endovascular procedure such as angiogram, angioplasty, embolization, IVC filter, TIPS (Transjugular Intrahepatic Portosystemic Shunt), catheter placement and chemoembolization and the other group of non-vascular procedure such as biopsy, drainage, ablation and cholangiography. The benefits are weighted against the risk of radiation exposure such as deterministic and stochastic effects. The interventional radiology staffs and patients usually receive high radiation dose during the procedures according to the increasing number of workloads and complexity of the procedures. Currently, there is no DRLs report of patient radiation dose in interventional radiology procedures in Thailand.

ICRP Publication 135 (5) title Diagnostic Reference Levels in Medical Imaging (2017) recommended on the DRLs to be proven as an effective tool that aids in optimization of protection in the medical exposure of patients for diagnostic and interventional procedures because the patient doses depend on the variety of factors in addition to different patient size, patient anatomy, lesion characteristics and disease severity. The DRLs process should be applied to both interventional fluoroscopy and interventional CT. In this publication, the commission introduced a concept of a typical value of local DRLs distribution for dose management in interventional fluoroscopy, and to consider stochastic effects. If the values of median of local DRLs quantities for patients are higher than the 75th percentile of National DRLs, the investigation should be started with the evaluation of the problem, then the procedure protocols, and finally the exposure techniques.

1.2 Research objective

To establish the local DRLs distribution of patient radiation dose and related parameters in interventional radiology procedures in standard-sized of Thai patients.

CHAPTER II
REVIEW OF RELATED LITERATURE

2.1 Theory

2.1.1 Interventional Radiology

2.1.1.1 Neuro-interventional radiology or Neuro IR (NIR)

Neuro-interventional radiology is a sub-specialize of minimally invasive surgical procedure that performed using medical fluoroscopy - angiography equipment taken digital subtraction angiography (DSA) technique to guide the medical angiography devices with contrast agent in the blood vessel through very small incision at the femoral artery in real time for diagnosis or treatment of diseases of head, neck and spine such as cerebral angiogram, Embolization of intracranial aneurysm and Embolization of brain AVM (arteriovenous malformation), etc.

2.1.1.2 Body interventional radiology

Body interventional radiology is performed for diagnostic and therapeutic procedures through very small body orifices. The interventional radiologists use common elements such as a puncture needle (to pass through the skin), guide wire (to guide the way of blood vessel), introducer sheath (to hold a vessel open and insert the other devices in blood vessel) and catheter (to permit contrast agent injection, withdrawal of fluids or to keep a passage open for treatment diseases) under medical imaging guidance, ultrasound, fluoroscopy, and CT to display the medical angiography devices in real time. The main benefit of interventional radiology is to decrease the infection risks, pain, and recovery well. Some interventional radiology procedure, the patients receive high radiation dose from x-ray imaging modality. For example, Trans Arterial Chemo Embolization (TACE), Catheter

placement, Percutaneous Drainage, Peripheral Endovascular procedure, and CT-guided Biopsy (Transthoracic needle biopsy: TTNB), etc.

2.1.2 Digital Subtraction Angiography (DSA) system

Digital subtraction angiography (DSA) (6) is a technique, begin in 1980s, using C-arm fluoroscopy system that can rotate around the floating-top table for visualizing blood vessels subtraction with contrast agent during interventional radiology procedures in the angiography unit.

DSA process offers the images of an area of interest that subtracted bony structure and background to increase contrast in the blood vessels. The pre-contrast image at the area of interest as a mask image subtracted with a post-contrast image at the same area while injecting contrast agent into the blood vessels. The images are useful for determining anatomical position and visualizing blood vessels accurately as in figure 2.1.

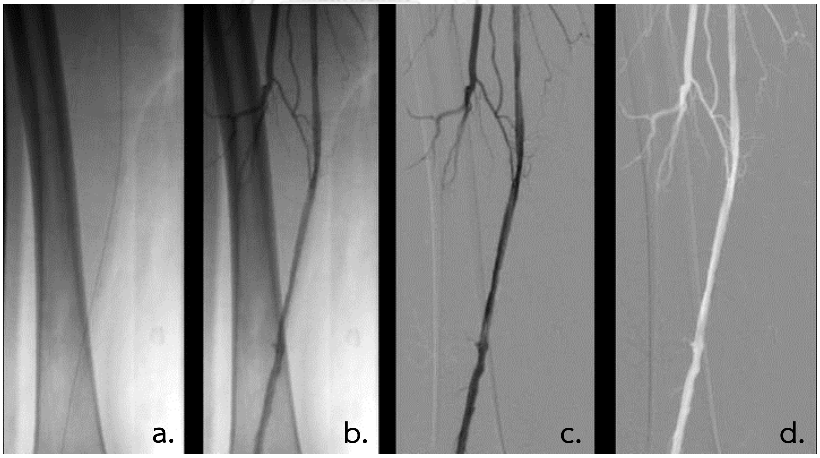

Figure 2. 1 Peripheral angiographic images, DSA technique (a. a mask image, b. a mask-contrast image, c. a subtracted image, d. an inverse subtracted image)

2.1.3 Radiation quantity

2.1.3.1 Air KERMA (AK)

Air KERMA (AK), Kinetic Energy Released per unit Mass (of air), is an indicator of medical X-ray fluoroscopy systems that monitored during the procedure in real time on system monitoring.

AK is used to measure at the interventional reference point, IRP, on the central axis of the X-ray beam at 15 cm from isocenter towards the X-ray tube (figure 2.2) in the units of joule per kilogram, J/kg, also the unit gray, Gy, for absorbed dose. Thus, AK at the interventional reference point in air will be equal to absorbed dose in the tissue.

2.1.3.2 Kerma-Area Product (KAP)

Kerma-Area Product (KAP) or Dose Area Product (DAP) recommended by ICRU report 74 (7) represents the product of the patient dose at the center of the X-ray beam and the area of the X-ray field, in the unit Gy.cm^2. The KAP value does not depend on the distance of measuring because of inverse square law, dose decreases when the area field increases. Thus, the KAP value is constant at any distance. KAP is an indicator of the patient radiation dose at skin during the interventional radiology procedure for estimating deterministic effects and stochastic risk to patients.

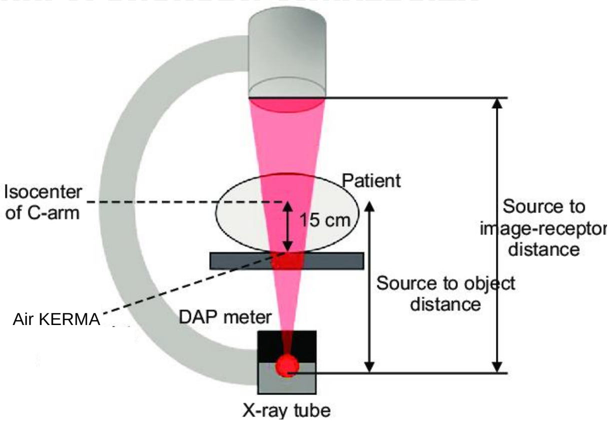

Figure 2. 2 Air KERMA at the interventional reference point and DAP meter, illustrated by Lee MY, Review article in: Progress in Medical Physics 2019.

2.1.4 ICRP Publication 135 Recommendation of Diagnostic Reference Levels in Medical Imaging

According to the ICRP publication 135 (2017) retaining the term of diagnostic reference level for the DRLs process applied to perform a medical imaging. DRLs should apply to interventional radiology procedures for considering optimize patient radiation dose. The following DRL quantities of interventional radiology are Cumulative air KERMA area product, KAP, Cumulative air KERMA, AK, Cumulative fluoroscopic time, and the number of radiographic images (i.e. cine images and digital subtraction angiography images in vascular procedures).

2.1.5 Diagnostic Reference Levels

Diagnostic Reference Levels (DRLs) had been used as an important tool for optimization the patient radiation dose in medical imaging. DRLs represent the general guideline based on 75th percentile of median dose distribution for a sample of patients based on standardized body weight range of adult patient. The sample data collected from 20-30 cases for DRLs distribution.

There are 4 terms of DRLs distribution.

- A typical value, the median value or 50th percentile of the DRLs distribution, is recommended for a group of local survey.
- Local DRLs (LDRLs) is the value of 75th percentile of median dose distribution using the data from a few healthcare centers in local area.
- National DRLs (NDRLs) represents the value of 75th percentile of median dose distribution of multiple healthcare centers in the country.
- Regional DRLs (RDRLs) is used for several countries in the region. RDRLs setting for two approaches as the median value of the National DRLs or the 75th percentile of median dose distribution of multiple healthcare centers in a region.

The Local DRLs, reviewed annually, should be lower than National DRLs, reviewed every 5 years. DRLs are not intended for individual patients, dose limit and border between good and bad practice because of image quality and patient radiation protection.

2.2 Review of related literature

In 2014, Erskine BJ et.al. (8) investigated Local diagnostic reference levels for angiographic and fluoroscopic procedures from Australian practice. The authors collected 38 types of procedures from 11,000 examinations, performed over 2.5 years at a major Australian public, and teaching hospitals. Each procedure type assessed, included a minimum of 50 cases. Local DRLs were defined for each procedure in terms of 75^{th} percentile of the basic related parameters such as fluoroscopy time (min), KERMA area product ($Gy.cm^2$) and procedural description. The 50^{th} and 95^{th} percentiles were calculated to demonstrate the spread of data.

The result showed Local DRLs distribution of the angiographic and fluoroscopic procedures for patient radiation dose optimization, as shown in Table 2.1

Table 2. 1 Angiographic Local DRLs – Abdominal interventional radiology procedures

Procedures	Median Fluoroscopy time(H:MM:SS)	KAP ($Gy.cm^2$)			No. of cases
		50^{th} percentile	(LDRL) 75^{th} percentile	95^{th} percentile	
Abdominal endovascular aortic repair (EVAR)	0:24:00	326.7	514.0	931.9	41
Abdominal gastrointestinal (GI) bleed	0:14:15	161.1	217.7	508.3	54
Abdominal splenic artery embolization	0:08:30	60.1	119.9	308.3	65
Abdominal hepatic transarterial chemoembolization (TACE)	0:30:00	208.7	385.2	513.4	52

The maximum patient radiation dose recorded was abdominal interventional radiology procedure. The maximum DAP of Local DRLs procedure was EVAR and the maximum median fluoroscopy time was TACE.

In 2019, Kim JS et.al. (9) investigated a multicenter survey of local diagnostic reference levels and achievable dose for coronary angiography and percutaneous transluminal coronary intervention procedures in Korea. This is the first study to introduce DRLs for cardiovascular interventional radiology procedures in Korea and the results help optimize the interventional cardiology procedures. The 1071 examinations (792 and 279 cases of CAG and PCI) were carried out in nine cardiovascular centers of the university hospitals in Korea, from August 2016 to October 2017. The DRLs distribution were based on 75th percentile and achievable dose (AD) based on 50th percentile to optimize the patient radiation dose using the average standard size of Korean people. The comparison of 75th percentile DRLs value of coronary angiography (CAG), percutaneous transluminal coronary intervention (PCI) procedures and preliminary DRLs proposed by IAEA, DIMOND III and SENTINEL, is shown in Table 2.2

Table 2. 2 Comparison of 75th percentile DRLs value of this study and preliminary DRLs proposed by IAEA, DIMOND III and SENTINEL.

	75th percentile DRLs in this study		75th percentile DRLs by IAEA		75th percentile DRLs by DIMOND III		75th percentile DRLs by SENTINEL	
	CAG	PCI	CAG	PCI	CAG	PCI	CAG	PCI
Cumulated KAP (Gy.cm^2)	47.00	171.26	53.10	92.00	57.00	94.00	45.00	85.00
Cumulated fluoroscopy time (s)	269.50	1338.25	360.00	960.00	360.00	960.00	390.00	930.00
Number of total images	675.50	1914.50	-	-	1270.00	1355.00	700.00	1000.00

Schegerer A et. al. (10) investigated the diagnostic reference levels for diagnostic and interventional X-Ray procedures in Germany: Update and Handling. The first National DRLs were established in Germany in 2003 and updated in 2010, 2016 and

2018, respectively, reported to the German Federal Office for Radiation Protection. The 25th, 50th and 75th percentiles of dose-related parameter values distribution of every procedures were determined. For the body interventional radiology procedures, DRLs in 2018 were updated and adjusted in comparison to the values from 2016. Since the updated National DRLs had been defined based on the 75th percentiles, the local DRLs provide the optimization on patient radiation dose to levels below the National DRLs.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Research design

This research is observational descriptive design in the type of retrospective study.

3.2 Conceptual framework

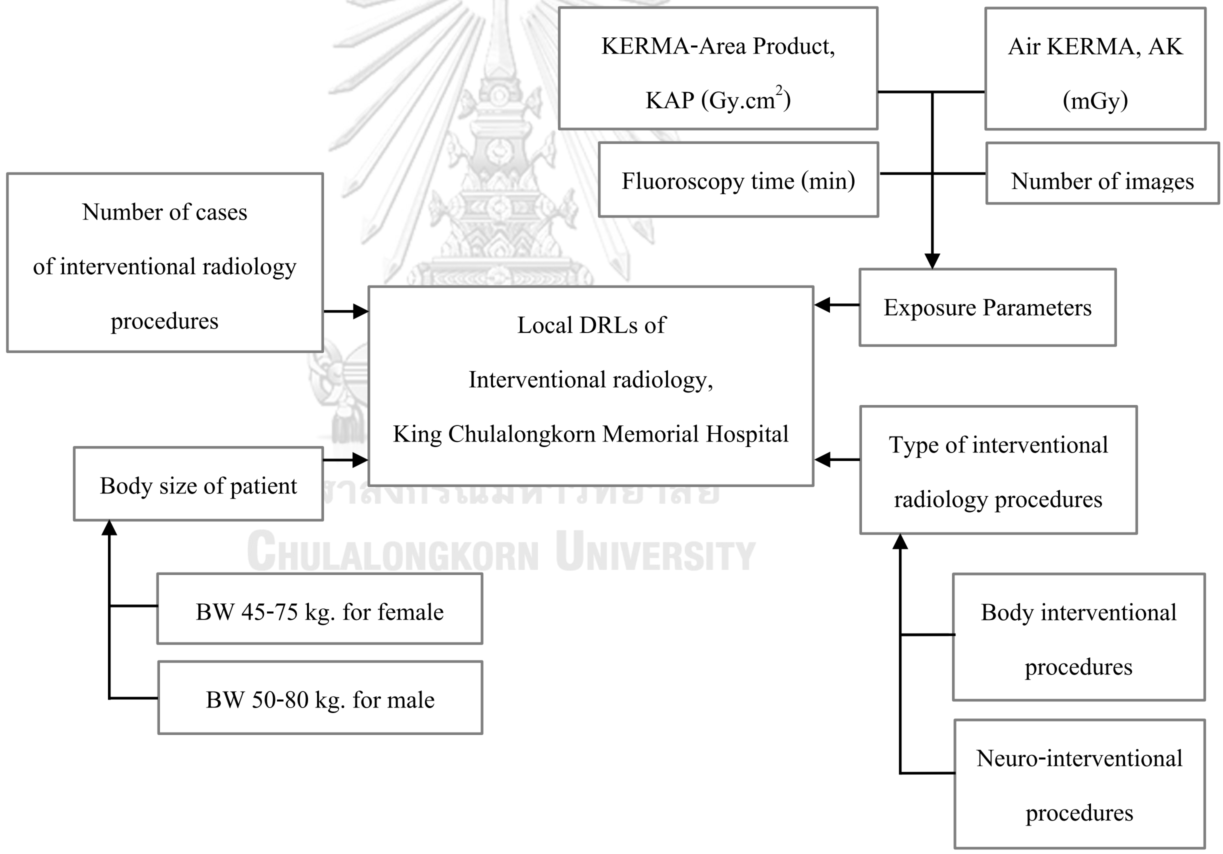

Figure 3. 1 Overview of conceptual framework

3.3 Research design model

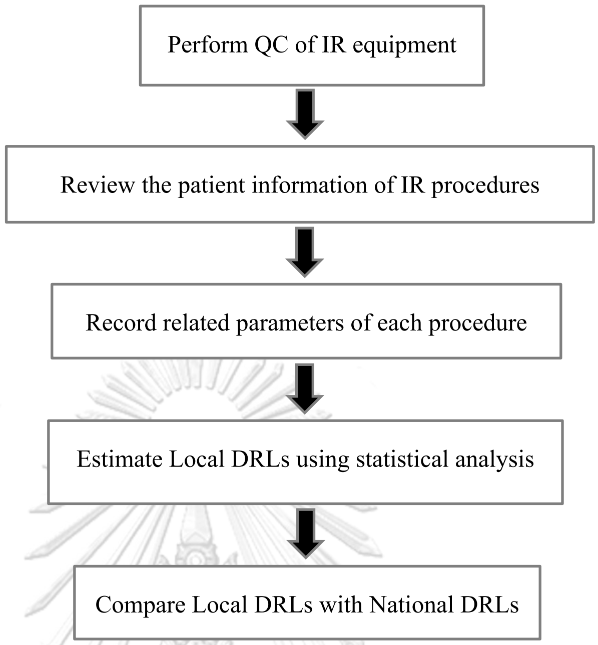

Figure 3. 2 Research design model of the local DRLs distribution

3.4 Research question

What is the local DRLs distribution of interventional radiology procedures at Unit of Vascular and Interventional Radiology, King Chulalongkorn Memorial Hospital?

3.5 Research objective

To establish the local DRLs distribution of patient radiation dose and related parameters in interventional radiology procedures in standard-sized of Thai patients.

3.6 Sample

3.6.1 Target population

The patients who underwent interventional radiology procedure at unit of vascular and interventional radiology, King Chulalongkorn Memorial Hospital, the data of neuro - interventional and the body interventional procedures will be collected in January - June 2020 period. Providing that some data of interventional radiology procedure is deficiency according to the pandemic COVID 19 result in the decreasing number of patients, the data collection will be extended to January 2019 - June 2020 period. In case that the patient underwent interventional radiology procedures more than one time in this period, all the data will be collected. No harm in collecting large number of patients than the plan to obtain better statistical results on DRLs.

3.6.2 Sample population

This research was a retrospective study. The data of the neuro-interventional and the body interventional procedures was collected from the dose procedure report from PACS and radiation dose management software (Radimetrics).

3.7 Eligible criteria

The data of patients collected from PACS system, is the retrospective data collecting, will be preserved in the locked laptop via the locked file using password.

3.7.1 Inclusion criteria

- Adult patient age at over 15 years old to match the standard size in Thai.
- Patients’ body weight 45-75 kg. for female, and 50-80 kg. for male.

Patients’ age and body weight are based on recommendation of the Thai Society of Vascular and Interventional Radiology and Department of Medical Sciences, Ministry of Public Health.

3.7.2 Exclusion criteria

- Patients age at less than 15 years old.
- Pregnant patient whose fetal dose should not be higher than 1 mSv during pregnancy.
- Patients body weight at outside the range recommended by the Professional Society.

3.8 Sample size determination

The sample population was determined using IAEA recommendation (1) of at least 20-30 cases per procedure from the clinical service at the Unit of Vascular and Interventional Radiology, King Chulalongkorn Memorial Hospital. There are 12 interventional radiology procedures of 3 neuro-interventional and 9 body interventional procedures in this study. Thus, total number of sample size for this study is at least 240 cases.

3.9 Materials

3.9.1 Quality Control of the equipment in the study using IAEA TRS 457 and AAPM Report no.58

3.9.1.1 Reference dosimeter

A solid state dosimeter for diagnostic radiology manufactured by IBA model XR multi-detector using MagicMaX universal multifunction for advanced beam verification and quality assurance for all x-ray imaging modalities (Figure 3.3) was used for exposure and fluoroscopy measurements

of dose, dose rate, time duration (ms), tube voltage (kVp), half value layer (HVL) and beam filtration.

a b

Figure 3. 3 Reference dosimeter, a. Solid state dosimeter (XR multi-detector), b. MagicMaX universal multifunction for advanced beam verification and quality assurance for all x-ray imaging modalities

3.9.1.2 Copper plate

Four copper plates of 0.5 mm thick and two copper plates of 1 mm thick, dimension 12 x 12 inch (30 x 30 cm.), used for driving tube voltage (kVp) during the QC of IR equipment (Figure 3.4)

Figure 3. 4 Copper plate

3.9.1.3 Collimator/Beam Alignment Test Tool

Collimator/Beam Alignment Test Tool manufactured by RMI model 07-661-7662 (Figure 3.5). Its surface etched of a flat 8 x 10 inch (20 x 25 cm.)

plate with a 14 x 18 cm pattern. It was used for field size assessment of IR equipment.

Figure 3. 5 Collimator/Beam Alignment Test Tool manufactured by RMI model 07-661-7662

3.9.1.4 TOR Leeds test object

TOR Leeds test object (Figure 3.6) used for checking of imaging performance such as monitor brightness, contrast level adjustment (highlight and lowlight details), Resolution limit (0.5 to 5.0 lp/mm), low-contrast large-detail detectability (18 details, 8mm diameter) and Circular Geometry (Lead Circle).

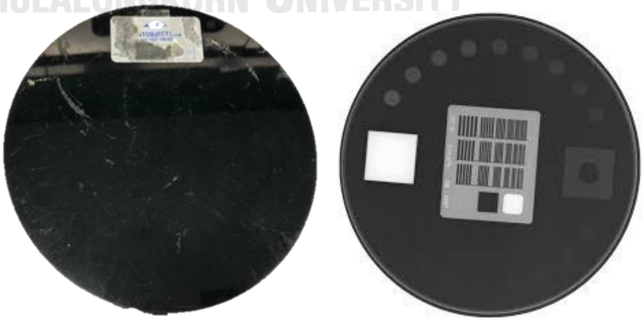

Figure 3. 6 TOR Leeds test object

3.9.1.5 Acrylic Phantom Material (PMMA slab phantom)

Acrylic Phantom Material is a polymethylmethacrylate (PMMA), represented a patient during the QC of IR equipment. Its density is 1.185 g/cm^3, the size is 25 x 25 cm^2 and 2 cm thick of each slab.

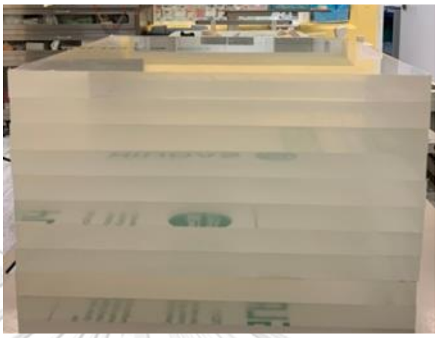

Figure 3. 7 Acrylic Phantom Material (PMMA slab phantom)

3.9.2 Research equipment

3.9.2.1 Angiographic equipment

3 neuro-interventional and 9 body interventional procedures were performed under hybrid angiography CT system, single plane fluoroscopy and biplane fluoroscopy systems.

- Canon (Toshiba) hybrid angiography CT system Model Infinix-i 4D CT, manufactured in July 2014.
- Philips biplane fluoroscopy Model Allura Clarity Xper FD20/15®, manufactured in March 2015.
- Siemens single plane fluoroscopy model Artis zee with PURE®, manufactured in May 2011.
- Siemens biplane fluoroscopy model Artis zee with PURE®, manufactured in March 2015

All the angiographic equipment were installed at the Unit of Vascular and Interventional Radiology, 7th Floor, Bhumisiri Mangkhalanusorn Building, King Chulalongkorn Memorial Hospital for interventional radiology procedures.

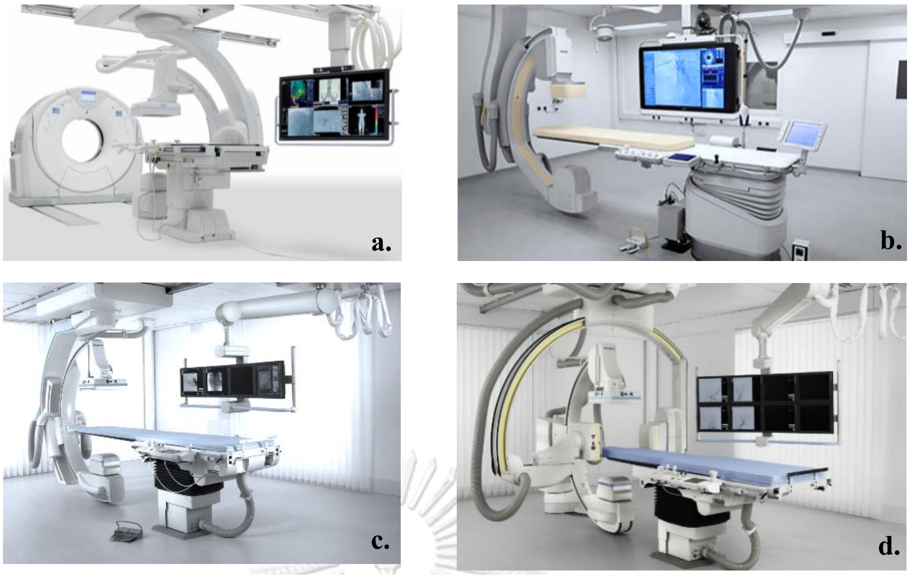

Figure 3. 8 Angiographic equipment a. Canon (Toshiba) hybrid angiography CT system model Infinix-i 4D CT, b. Philips biplane fluoroscopy model Allura Clarity Xper FD20/15®, c. Siemens single plane fluoroscopy model Artis zee with PURE®, d. Siemens biplane

The systems equipped with a KAP meter (KERMA area product) and the parameters displayed at the end of procedure on the operator console are

- Cumulative air KERMA area product, KAP ($Gy.cm^2$)
- Cumulative air KERMA, AK (mGy)
- Tube voltage (kVp), Tube current time (mAs)
- Acquisition protocols and exposure modes (DSA, Cone beam CT and fluoroscopy)
- Cumulative fluoroscopic time (minute)
- Total number of images

3.9.2.2 The patient information in electronic medical record, EMR.

3.9.2.3 Picture archiving and communication system, PACS

3.9.2.4 Radiation dose management software, Radimetrics

3.9.2.5 Case record form

3.10 Methods

3 neuro-interventional and 9 body interventional procedures were performed under angiographic equipment such as

- CT-guided Transarterial Chemo Embolization (CT-guided TACE) was performed using Canon (Toshiba) hybrid angiography CT system
- CBCT-guided Biopsy (Transthoracic needle biopsy: TTNB), Cerebral angiogram, Embolization of intracranial aneurysm and Embolization of brain Arteriovenous malformation (AVM) using Philips biplane fluoroscopy system
- CBCT-guided Transarterial Chemo Embolization (CBCT-guided TACE), Peripheral Inserted Central Catheter (PICC line), Permanent double lumen catheter (Perm cath), Percutaneous Collection Drainage (PCD) and Percutaneous Transhepatic Biliary Drainage (PTBD) using Siemens single plane fluoroscopy system
- Peripheral angiogram and Peripheral angioplasty using Siemens biplane fluoroscopy system

3.10.1 Perform QC of angiographic equipment using IAEA TRS 457 (11) and AAPM Report no.58 (12) as the following:

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

3.10.2 Review the standard size of patients from EMR. (45-75 kg. for female, 50-80 kg. for male based on basic criteria of the Thai Society of Vascular and Interventional Radiology)

Record the patient information of each procedure on the gender, age, body weight and height.

3.10.3 Collect the exposure and related parameters from PACS and Radimetrics.

- Cumulative fluoroscopic time (minute)
- Cumulative Air KERMA, AK (mGy)
- Cumulative KERMA area product, KAP ($Gy.cm^2$)
- Total number of images

3.10.4 Analyze the collected data using descriptive statistics via statistical package SPSS version 22, IBM, USA such as maximum, minimum, average, standard deviation, 25^{th} percentile, 50^{th} percentile (median), 75^{th} percentile and interquartile range.

3.10.5 Compare Local DRLs to National DRLs and other studies.

3.11 Variables measurement

Measure independent and dependent variables as following

3.11.1 Independent variables

Type of procedure, interventional radiologist skill, staff experience and type of angiographic equipment, case complexity index.

3.11.2 Dependent variables

Cumulative fluoroscopic time (minute), cumulative Air KERMA, AK (mGy), cumulative KERMA area product, KAP ($Gy.cm^2$) and total number of images.

3.12 Statistical analysis

This study is descriptive statistics for Local DRLs distribution. The following statistics will be analyzed via statistical package SPSS version 22, IBM, Armonk, New York, USA.

- Minimum
- Maximum
- Average
- Standard deviation
- 25th percentile, 50th percentile (Median), 75th percentile
- Interquartile range

3.13 Data analysis

The Local DRLs distribution were reported as maximum, minimum, average, standard deviation, 25th percentile, 50th percentile (median), 75th percentile in the form of table and Interquartile range in boxplots.

3.14 Outcomes

The local DRLs distribution of 3 neuro-interventional and 9 body interventional procedures at Unit of Vascular and Interventional Radiology, King Chulalongkorn Memorial Hospital is determined.

3.15 Expected benefits

This study is the first Local DRLs for interventional radiology procedures in Thailand. The optimization of the radiation dose to the patients during the procedures at the unit of vascular and interventional radiology, King Chulalongkorn Memorial Hospital is the most benefit to patients for the radiation risk reduction.

3.16 Limitation

Less number of interventional radiology patients during COVID-19 was observed.

3.17 Ethical consideration

As this study involves the optimization of patient radiation dose, the patient information and procedure report were extracted from electronic medical record, EMR, PACS and Radimetrics. The research proposal was submitted to the ethic committee for the approval by Institutional Review Board (IRB) of the Faculty of Medicine, Chulalongkorn University, Bangkok, Thailand.

CHAPTER IV
RESULTS

4.1 Quality control of the angiographic equipment

The quality control test of the hybrid angiography CT system, single plane and biplane fluoroscopy systems was performed by following IAEA TRS 457 (11) and AAPM Report no.58 (12). The protocols include the electromechanical component tests, dose assessment, Automatic Brightness Control test, maximum dose rate assessment, field size assessment, Table attenuation, Half Value Layer (HVL) and Image quality assessment. The results are shown in the Appendix.

4.2 The patient information

The patient information of 12 interventional radiology procedures (3 neuro-interventional and 9 body interventional procedures) was reviewed between January 2019 and June 2020 from Electronic Medical Record (EMR) of 485 cases; neuro-intervention 87 cases, body intervention 398 cases. Thai Society of Vascular and Interventional Radiology, and Department of Medical Sciences, Ministry of Public Health recommended the standard sizes of Thai female at 45-75 kg. and 50-80 kg. for Thai male. The patient information was gender, age, body weight and height as shown in table 4.1 and 4.2 respectively.

The average and standard deviation of the age, body weight and height of the neuro-interventional patients who underwent Cerebral angiogram were 56±14 years old, 61±9 kg., and 164±8 cm., respectively. The average age, body weight and height of patients who underwent Embolization of intracranial aneurysm were 57±16 years old, 59±7 kg., 163±5 cm., respectively. The average age, body weight and height of patients who underwent Embolization of brain AVM were 37±11 years old, 62±10 kg., and 167±6 cm., respectively as shown in table 4.1.

The average and standard deviation of the age, body weight and height of the body interventional patients who underwent CT-guided TACE were 64±10 years old, 65±8 kg., and 165±7 cm., respectively. The average and standard deviation of the age, body weight and height of the CBCT-guided TACE patients were 62±12 years old, 62±10 kg., and 164±9 cm., respectively. The average and standard deviation of the age, body weight and height of the PICC line patients were 54±19 years old, 58±8 kg., and 161±8 cm., respectively. The average and standard deviation of the age, body weight and height of the Perm cath patients were 70±18 years old, 61±8 kg., and 162±7 cm., respectively. The average and standard deviation of the age, body weight and height of the PCD patients were 61±17 years old, 61±7 kg., and 163±7 cm., respectively. The average and standard deviation of the age, body weight and height of the PTBD patients were 57±13 years old, 60±8 kg., and 165±8 cm., respectively. The average and standard deviation of the age, body weight and height of the Peripheral angiogram patients were 66±19 years old, 64±9 kg., and 165±10 cm., respectively. The average and standard deviation of the age, body weight and height of the Peripheral angioplasty patients were 69±11 years old, 62±8 kg., and 164±9 cm., respectively. The average and standard deviation of the age, body weight and height of the CBCT-guided Biopsy patients were 66±11 years old, 60±8 kg., and 163±7 cm., respectively as shown in table 4.2.

Table 4. 1 Patient information of the Neuro-interventional Procedures

Patient information	Neuro-interventional Procedures		
	Cerebral angiogram	Embolization of intracranial aneurysm	Embolization of brain AVM
Gender			
Female	21	13	7
Male	23	10	13
Age (Y)			
Average	56	57	37
(Min-Max)	(20-70)	(24-83)	(15-58)
SD	14	16	11

Body weight (kg.)			
Average	61	59	62
(Min-Max)	(45-78)	(49-70)	(50-80)
SD	9	7	10
Height (cm.)			
Average	164	163	167
(Min-Max)	(148-178)	(153-170)	(160-180)
SD	8	5	6

Table 4. 2 Patient information of the Body interventional Procedures

Patient information	Body interventional Procedures								
	CT-guided TACE	CBCT-guided TACE	PICC line	Perm cath	PCD	PTBD	Peripheral angiogram	Peripheral angioplasty	CBCT-guided Biopsy
Gender									
Female	23	6	39	10	15	9	6	22	22
Male	89	20	19	14	19	11	14	26	23
Age (Y)									
Average	64	62	54	70	61	57	66	69	66
(Min-Max)	(35-87)	(34-83)	(16-92)	(16-89)	(21-86)	(25-82)	(23-84)	(41-86)	(24-85)
SD	10	12	19	18	17	13	19	11	11
Body weight (kg.)									
Average	65	62	58	61	61	60	64	62	60
(Min-Max)	(49-81)	(50-79)	(45-80)	(48-77)	(47-75)	(45-79)	(50-80)	(47-80)	(47-75)
SD	8	10	8	8	7	8	9	8	8
Height (cm.)									
Average	165	164	161	162	163	165	165	164	163
(Min-Max)	(141-186)	(148-178)	(148-187)	(148-175)	(148-175)	(145-180)	(146-185)	(147-180)	(150-180)
SD	7	9	8	7	7	8	10	9	7

4.3 The exposure and related parameters

The parameters related to the exposure such as cumulative fluoroscopic time (minute), cumulative air KERMA, CAK (mGy), cumulative KERMA area product, KAP ($Gy.cm^2$) and total number of images during neuro-interventional and body interventional procedures had been recorded and shown in Table 4.3 and 4.4, respectively.

Table 4. 3 The parameters related to exposure of Neuro-interventional Procedures

Patient information	Neuro-interventional Procedures		
	Cerebral angiogram	Embolization of intracranial aneurysm	Embolization of brain AVM
Cumulative Fluoroscopy time (min)			
Average	9.77	42.60	43.61
(Min-Max)	(1.52-55.05)	(11.57-78.48)	(4.41-115.14)
SD	9.27	20.27	28.45
25^{th} percentile	4.55	23.37	18.90
50^{th} percentile	6.53	39.48	44.16
75^{th} percentile	11.48	62.06	63.51
Cumulative AK (mGy)			
Average	444.56	1513.62	1679.78
(Min-Max)	(130.92-1548.73)	(221.12-3750.67)	(255.95-4236.76)
SD	314.32	895.71	1064.61
25^{th} percentile	278.71	1098.88	1016.61
50^{th} percentile	346.21	1427.82	1595.15
75^{th} percentile	410.32	1737.68	2315.22
Cumulative KAP ($Gy.cm^2$)			
Average	56.71	122.97	165.33
(Min-Max)	(17.83-157.37)	(39.53-246.47)	(39.54-343.73)
SD	29.28	53.22	80.56
25^{th} percentile	39.13	98.87	104.20

50^{th} percentile	48.82	120.50	156.84
75^{th} percentile	60.73	143.78	224.29
Total No. of images			
Average	288	877	1987
(Min-Max)	(82-768)	(276-2063)	(182-5566)
SD	152	488	1409
25^{th} percentile	167	459	1051
50^{th} percentile	240	754	1858
75^{th} percentile	351	1227	2589

Table 4. 4 The parameters related the exposure of the Body interventional Procedures

Patient information	Body interventional Procedures								
	CT-guided TACE	CBCT-guided TACE	PICC line	Perm cath	PCD	PTBD	Peripheral angiogram	Peripheral angioplasty	CBCT-guided Biopsy
Cum Flu time (min)									
Average	61.14	55.15	1	2.36	1.84	4.75	8.63	22.02	2.58
(Min-Max)	(13.12-150.30)	(17.50-101.80)	(0.20-8)	(0.10-18.60)	(0.47-6.00)	(0.34-15.30)	(0.23-34.20)	(0.80-126.90)	(0.09-6.26)
SD	27.81	26.23	1.07	3.59	1.40	3.33	9.42	24.78	1.41
25^{th} percentile	39.65	31.83	0.50	0.90	0.90	2.50	1.85	8.03	1.50
50^{th} percentile	58.30	53.75	0.70	1.65	1.40	4.65	5.61	15.40	2.19
75^{th} percentile	79.74	80.35	1.33	2.48	2.33	6.125	12.45	27.25	3.24
CAK (mGy)									
Average	2456.77	1725.83	2.43	10.15	12.66	51.93	43.76	42.19	64.23
(Min-Max)	(488-14442)	(624.50-6319)	(0.50-11.80)	(0.70-64.80)	(0.90-83.30)	(1.75-239.50)	(1.57-258.60)	(4.30-190.90)	(21.76-193.03)
SD	1861.39	1205.33	1.99	14.37	15.83	68.80	58.62	45.50	39.57
25^{th} percentile	1348	1109.33	1.30	2.75	3.98	17.70	8.63	12.33	38.93
50^{th} percentile	2055	1410	1.80	3.60	7.80	25.70	19.05	23.80	55.68
75^{th} percentile	2777	1874.75	3	12.08	14.55	52.65	69.15	49.95	74.10
Cum KAP ($Gy.cm^2$)									
Average	342.92	307.41	0.96	3.15	2.80	9.43	9.23	11.30	13.87
(Min-Max)	(107.93-913.37)	116.46-1167.49)	(0.18-3.20)	(0.29-19.53)	(0.36-8.78)	(0.78-33.88)	(0.36-29.3)	(1.33-41.67)	(4.04-49.50)

SD	190.48	210.43	0.72	4.26	2.08	8.81	9.15	9.92	8.71
25^{th} percentile	195.73	190.39	0.48	0.85	1.29	3.96	2.10	4.09	8.06
50^{th} percentile	286.68	238.27	0.70	1.16	2.29	5.56	3.73	7	11.65
75^{th} percentile	459.27	356.97	1.19	3.96	3.99	13.77	17.61	16.20	17.39
Total No. of images									
Average	326	423	3	6	5	10	252	263	1351
(Min-Max)	(103-766)	(159-956)	(1-5)	(2-39)	(2-18)	(3-76)	(47-822)	(21-1530)	(48-3756)
SD	132	211	1	7	3	16	185	261	535
25^{th} percentile	227	268	3	3	3	6	122	103	1000
50^{th} percentile	318	382	3	4	4	7	183	180	1252
75^{th} percentile	417	561	3	6	5	9	336	336	1574

Cum Flu Time: Cumulative Fluoroscopy Time, CAK: Cumulative Air KERMA, Cum KAP, Cumulative KERMA Area Product, SD: Standard Deviation

4.4 Local Diagnostic Reference Levels (LDRLs) distribution

LDRLs of the neuro-interventional and body interventional procedures at King Chulalongkorn Memorial Hospital were established in 2020. The LDRLs as the 25^{th} percentile, 50^{th} percentile (median or typical value), 75^{th} percentile of cumulative fluoroscopy time (min), KERMA Area Product (KAP, Gy.cm^2), and the effective dose (mSv), calculated by dose conversion coefficient from UNSCEAR (13) were shown in Table 4.5

DRLs of the neuro-interventional procedures, the KAP at median and 75^{th} percentile (DRLs) and effective dose of Cerebral angiogram were 49 Gy.cm^2, 61 Gy.cm^2, 5.28 mSv , Embolization of intracranial aneurysm were 121 Gy.cm^2, 144 Gy.cm^2 , 37.38 mSv and Embolization of brain AVM were 157 Gy.cm^2, 224 Gy.cm^2 , 58.32 mSv, respectively. The maximum DRLs of neuro-intervention procedures is Embolization of brain AVM as a therapeutic procedure as shown in Table 4.5 and Figure 4.1.

For the body interventional procedures, the value of KAP at median and 75^{th} percentile (DRLs) and effective dose of CT-guided TACE were 287 Gy.cm^2, 459 Gy.cm^2, 119 mSv, CBCT-guided TACE were 238 Gy.cm^2, 397 Gy.cm^2, 93 mSv. The median and 75^{th} percentile of PICC line were 0.7 Gy.cm^2, 1 Gy.cm^2, Perm cath were 1 Gy.cm^2, 4 Gy.cm^2, PCD were 2 Gy.cm^2, 4 Gy.cm^2, PTBD were 6 Gy.cm^2, 14 Gy.cm^2, Peripheral angiogram were 4 Gy.cm^2, 18 Gy.cm^2, the effective dose was 5 mSv, Peripheral angioplasty were 7 Gy.cm^2, 16 Gy.cm^2, 4 mSv, CBCT-guided Biopsy were 12 Gy.cm^2, 17 Gy.cm^2, respectively. The maximum DRLs of body interventional procedures is CT-guided TACE as shown in Table 4.5 and Figure 4.2.

Table 4. 5 Median of fluoroscopy time (min), 25th percentile, 50th percentile (median), 75th percentile (DRLs) of KAP (Gy.cm²) values, median No. of images and Effective dose (mSv) of interventional radiology procedures

Interventional Radiology Procedures	Median Flu time (min)	KAP (Gy.cm²) 25th percentile	KAP (Gy.cm²) 50th percentile (Median)	KAP (Gy.cm²) 75th percentile (DRLs)	Median No. of images	Effective dose (mSv)
Neuro- Intervention						
Cerebral angiogram	6.53	39.13	48.82	60.73	240	5.28
Embolization of intracranial aneurysm	39.48	98.87	120.50	143.78	754	37.38
Embolization of brain AVM	44.16	104.20	156.84	224.29	1858	58.32
Body Intervention						
CT-guided TACE	58.30	195.73	286.68	459.27	318	119.41
CBCT-guided TACE	53.75	190.39	238.27	356.97	382	92.81
PICC line	0.70	0.48	0.70	1.19	3	-
Perm cath	1.65	0.85	1.16	3.96	4	-
PCD	1.40	1.29	2.29	3.99	4	-
PTBD	4.65	3.96	5.56	13.77	7	-
Peripheral angiogram	5.25	2.10	3.73	17.61	183	4.58
Peripheral angioplasty	15.40	4.09	7.00	16.20	180	4.21
CBCT-guided Biopsy	2.19	8.06	11.65	17.39	1252	-

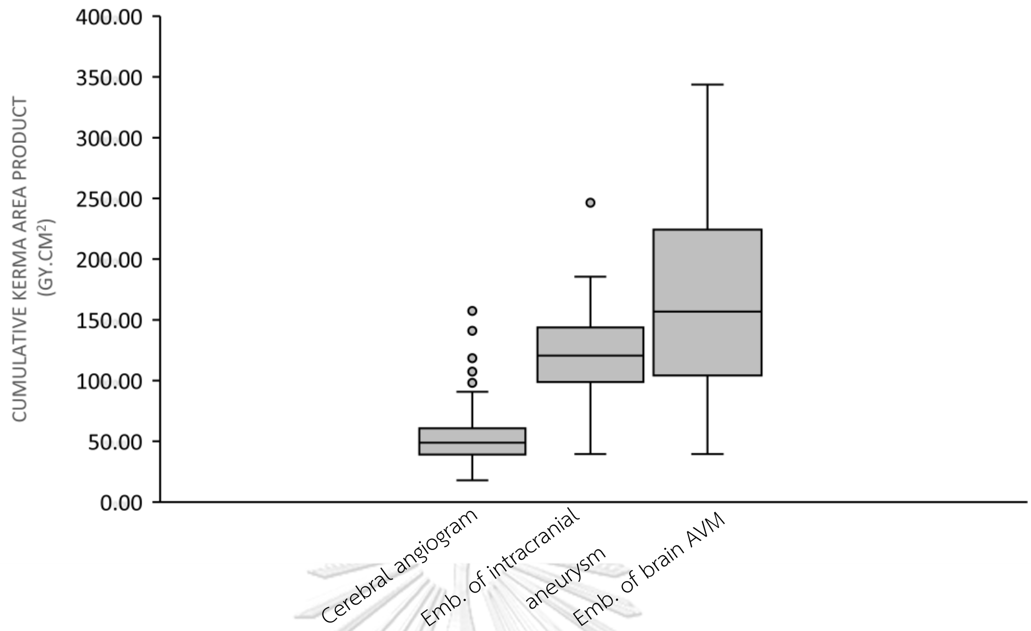

Figure 4. 1 Minimum, maximum, 25th percentile, 50th percentile (median), 75th percentile (DRLs) values of neuro-interventional procedures

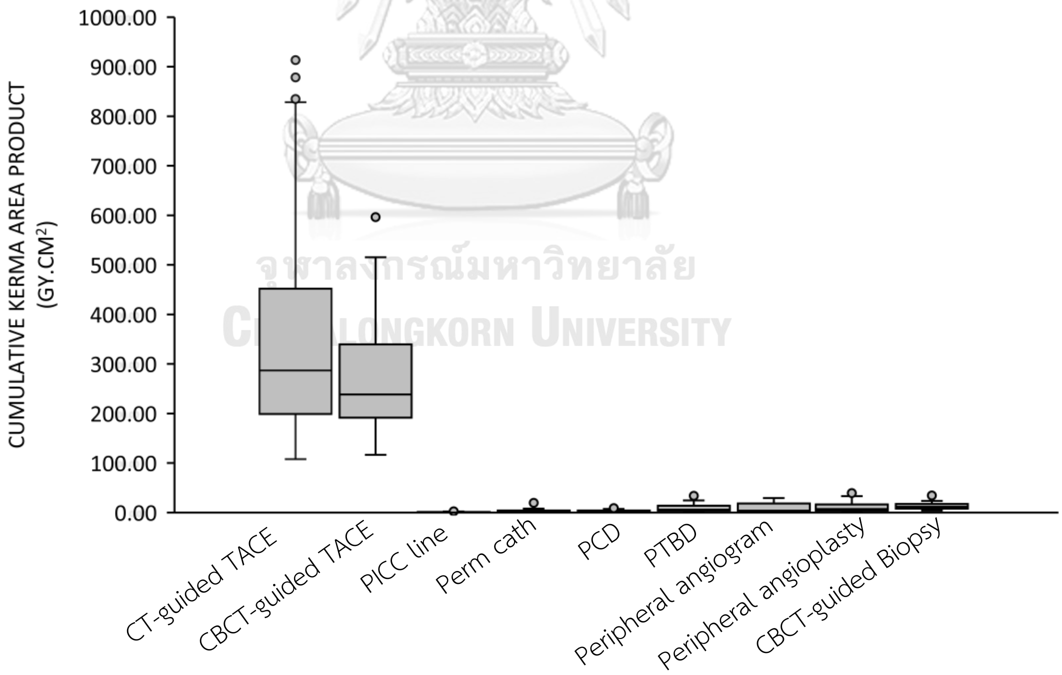

Figure 4. 2 Minimum, maximum, 25th percentile, 50th percentile (median), 75th percentile (DRLs) values of body interventional procedures

4.5 Comparison of LDRLs to NDRLs

50^{th} percentile (median) of KAP ($Gy.cm^2$) value of some interventional radiology procedures in this study had been compared to 50th percentile (median) of Erskine's LDRLs study (8), 75^{th} percentile of Schegerer's NDRLs study (10), Japan DRLs 2020 (14) and Thailand DRLs 2021.

Our study on two neuro-interventional radiology procedures were compared to Erskine's study and Thailand DRLs 2021 such as Cerebral angiogram: 50 $Gy.cm^2$, 83 $Gy.cm^2$, 273 $Gy.cm^2$ and Embolization of intracranial aneurysm: 122 $Gy.cm^2$, 153 $Gy.cm^2$, 183 $Gy.cm^2$, respectively. Embolization of brain AVM in this study was compared to Japan DRLs 2020 and Thailand DRLs 2021: 157 $Gy.cm^2$, 410 $Gy.cm^2$, 178 $Gy.cm^2$.

CBCT-guided TACE procedure in this study was compared to all studies, Erskine's study and Schegerer's study, and both NDRLs, Japan DRLs 2020 and Thailand DRLs 2021: 238 $Gy.cm^2$, 285 $Gy.cm^2$, 224 $Gy.cm^2$, 270 $Gy.cm^2$, 297 $Gy.cm^2$, respectively. Our study of two body interventional radiology procedures were compared to Thailand DRLs such as PTBD: 6 $Gy.cm^2$, 13 $Gy.cm^2$, CBCT-guided Biopsy 17 $Gy.cm^2$, 249 $Gy.cm^2$ as shown in Table 4.6.

Table 4. 6 Comparing 50^{th} percentile in this study to Erskine's study, Schegerer's study, Japan DRLs 2020 and Thailand DRLs.

Interventional Procedures	Median this study ($Gy.cm^2$)	Median Erskine's study (Gy.cm2)	75^{th} percentile Schegerer's study (Gy.cm2)	75^{th} percentile Japan DRLs 2020 ($Gy.cm^2$)	75^{th} percentile Thailand DRLs 2021 ($Gy.cm^2$)
Neuro-intervention					
Cerebral angiogram	49	83	-	-	273
Embolization of intracranial aneurysm	121	153	-	-	183
Embolization of brain AVM	157	-	-	410	178

Body intervention					
CBCT-guided TACE	238	385	224	270	297
PTBD	6	-	-	-	13
CBCT-guided Biopsy	12	-	-	-	249

CHAPTER V
DISCUSSION AND CONCLUSION

5.1 LDRLs of the interventional radiology procedures

The LDRLs have been established using the data of Thai patient radiation dose received from the interventional radiology procedures performed at a department of a university-hospital. The 50th percentile (median) level of the value of KAP is close to the 25th percentile that means the patient doses are quite low for the interventional radiology procedures while the image quality is still appropriate. LDRLs are increasingly important for hospitals to optimize the patient radiation doses.

5.1.1 Neuro-interventional radiology procedure

From Table 4.3, the value of KAP at 75th percentile of Cerebral angiogram, diagnostic procedure, is less than therapeutic procedure, Embolization of intracranial aneurysm and Embolization of brain AVM because the diagnostic procedure used only 2D and 3D DSA techniques via biplane fluoroscopy system to diagnose the disease of brain while therapeutic procedure used 2D, 3D and CBCT DSA techniques during the procedures as shown in the case record form in Appendix. The value of KAP at 75th percentile of Embolization of brain AVM is the maximum DRLs in NIR because of the specificity of the disease, and the acquisition mode selected during the procedure.

5.1.2 Body interventional radiology procedure

From Table 4.4, the value of KAP at 75th percentile of CT-guided TACE is higher than CBCT-guided TACE because CT-guided TACE procedure use Hybrid

angiography CT system for DSA technique and CT scan to guide the medical devices in the small blood supply to the tumors in the liver of patient during the procedure while CBCT-guided use DSA and CBCT techniques of the single plane fluoroscopy. The equipment selection depends on case complexity index and radiologist's decision.

Catheter placement procedures in this study used the same equipment as single plane fluoroscopy system. The value of KAP at 75^{th} percentile of Perm cath is higher than PICC line procedure because of the different location of the catheter insertion for different purpose to treat the disease. PICC line inserted the body through the skin at a peripheral site to deliver parenteral nutrition, chemotherapy, or long term medication treatments while Perm cath inserted through the neck at the right internal jugular vein for exchanging blood from a hemodialysis machine and a patient.

Nonvascular procedures, PCD and PTBD procedures used the same equipment as single plane fluoroscopy system for drainage fluid at the abdomen area, but CBCT-guided Biopsy used CBCT technique of biplane fluoroscopy system to guide the biopsy needle in thoracic area. Thus, the value of KAP at 75^{th} percentile of CBCT-guided Biopsy is higher than PCD and PTBD procedures.

Peripheral vascular procedure, the value of KAP at 75^{th} percentile of Peripheral angiogram is higher than Peripheral angioplasty, but the median of fluoroscopy time of angiogram is less than angioplasty because of pulse rate, acquisition mode and the lack of sample size that influence to the spreading of the data.

5.2 Comparison of LDRLs to NDRLs

The value of KAP at 50^{th} percentile (median) of interventional radiology procedures in this study had been compared to 50^{th} percentile (median) of Erskine's LDRLs study (8) and 75^{th} percentile of Schegerer's NDRLs study (10) as literature review. As the patients of Japan and Thailand are Asian, the value of KAP at 50^{th} percentile (median) of interventional radiology procedures in this study had been compared to 75^{th} percentile of Japan DRLs 2020 (14) and Thailand DRLs 2021. The 50^{th} percentile (median) of LDRLs should be less than 75^{th} percentile of NDRLs as in Table 4.6. The LDRLs should be reviewed annually.

Neuro-interventional radiology procedures, the 50^{th} percentile (median) value in Table 4.6, are less than all studies and both NDRLs because the senior interventional radiologists conduct and teach the fellows during the complicated procedures.

For Body interventional radiology procedures, the 50^{th} percentile (median) value of CBCT-guided TACE is higher than Schegerer's study but less than Erskine's study and both NDRLs. The median of PTBD and CBCT-guided Biopsy procedure are also less than Thailand DRLs 2021 because this center is a university-hospital. There are many more modalities to support the clinical services and training fellows. As this center is a tertiary care, most of the cases are at high complexity index, the exposure techniques should be evaluated including the image quality.

5.3 The factors affected the patient radiation dose during interventional radiology procedures

5.3.1 Thickness of the body part

As the patient thickness on different body parts is variable, the Automatic Brightness Control (ABC) will control the tube current time, mAs, according to the body thickness to reach the optimization during the interventional

radiology procedure. The patient entrance surface dose, the image quality and the monitor brightness will be acceptable.

5.3.2 The complexity index

The complexity index is one of the factors affecting the patient radiation dose. The interventional radiologist will decide the technique of fluoroscopy system such as 2D DSA, 3D DSA, CT-guided and CBCT- guided of angiographic equipment and choose the angiographic materials for treatment. The equipment and materials chosen would be appropriate for the patient complexity index.

5.3.3 The angiographic equipment

Hybrid angiography CT system and the single or biplane fluoroscopy were chosen suitably to support the interventional radiologists in performing the interventional radiology procedures.

5.3.4 The angiographic materials

There are many types and brands of angiography materials that used for interventional radiology procedures. The selection of the angiographic materials depends on the complexity index of the disease and the interventional radiologist's decision.

5.3.5 The exposure techniques

The proper exposure techniques such as Air KERMA (AK), KERMA Area Product (KAP), total exposure time, beam collimation, pulse rate and acquisition mode affected the optimization of patient radiation dose include the image quality during the interventional radiology procedures. The proper exposure technique used for the patient radiation dose reduction would decrease the deterministic effects and the stochastic risk to the patients.

5.3.6 The interventional radiologists' skill and decision.

The senior and competence interventional radiologists can conduct, decide and perform the interventional radiology procedures accurately in the short time. This will result in the lower patient dose in comparison to the performance of the fellows.

5.4 Conclusion

The LDRLs of patient radiation dose and related parameters of interventional radiology procedures had been thoroughly studied at KCMH.

5.4.1 Neuro-interventional procedures

Cerebral angiogram

- The KAP at median and 75^{th} percentile (DRLs) were 49 $Gy.cm^2$ and 61 $Gy.cm^2$.
- The median of fluoroscopy time and AK were 6.53 min and 346 mGy.

Embolization of intracranial aneurysm

- The KAP at median and 75^{th} percentile (DRLs) were 121 $Gy.cm^2$ and 144 $Gy.cm^2$.
- The median of fluoroscopy time and AK were 39.48 min and 1428 mGy.

Embolization of brain AVM

- The KAP at median and 75^{th} percentile (DRLs) were 157 $Gy.cm^2$ and 224 $Gy.cm^2$
- The median of fluoroscopy time and AK were 44.16 min and 1596 mGy.

5.4.2 Body interventional procedures.

CT-guided TACE

- The KAP at median and 75^{th} percentile (DRLs) were 287 $Gy.cm^2$ and 459 $Gy.cm^2$.

- The median of fluoroscopy time and AK were 58.30 min and 2055 mGy.

CBCT-guided TACE

- The KAP at median and 75th percentile (DRLs) were 238 Gy.cm^2 and 397 Gy.cm^2.
- The median of fluoroscopy time and AK were 53.75 min and 1410 mGy.

PICC line

- The KAP at median and 75th percentile (DRLs) were 0.7 Gy.cm^2 and 1 Gy.cm^2.
- The median of fluoroscopy time and AK were 0.70 min and 1.80 mGy.

Perm cath

- The KAP at median and 75th percentile (DRLs) were 1 Gy.cm^2 and 4 Gy.cm^2.
- The median of fluoroscopy time and AK were 1.65 min and 3.60 mGy.

PCD

- The KAP at median and 75th percentile (DRLs) were 2 Gy.cm^2 and 4 Gy.cm^2.
- The median of fluoroscopy time and AK were 1.40 min and 7.80 mGy.

PTBD

- The KAP at median and 75th percentile (DRLs) were 6 Gy.cm^2 and 14 Gy.cm^2.
- The median of fluoroscopy time and AK were 4.65 min and 25.70 mGy.

Peripheral angiogram

- The KAP at median and 75th percentile (DRLs) were 4 Gy.cm^2 and 18 Gy.cm^2.
- The median of fluoroscopy time and AK were 5.61 min and 19.05 mGy.

Peripheral angioplasty

- The KAP at median and 75th percentile (DRLs) were 7 $Gy.cm^2$ and 16 $Gy.cm^2$.
- The median of fluoroscopy time and AK were 15.40 min and 23.80 mGy.

CBCT-guided Biopsy

- The KAP at median and 75th percentile (DRLs) were 12 $Gy.cm^2$ and 17 $Gy.cm^2$.
- The median of fluoroscopy time and AK were 2.19 min and 55.68 mGy.

The patient radiation dose from interventional radiology procedures should be optimized and reviewed annually, particularly in the therapeutic procedures i.e. Embolization of intracranial aneurysm, Embolization of brain AVM and TACE, for evaluation of the exposure technique, decreasing the risk of radiation dose to patient and reducing scattered radiation to all staffs.

The LDRLs of interventional radiology procedures is the first establishment in 2020 while Thailand DRLs is established in 2021. The outcome of this study will help in optimizing the patient radiation dose for the unit of vascular and interventional radiology at King Chulalongkorn Memorial Hospital. The LDRLs report is useful in providing guidance on NDRLs database.

APPENDIX A CASE RECORD FORM

Case record form

Table A. 1 Data collection for body interventional procedure

Angiographic equipment:

Model: ☐ Single plane ☐ Biplane

Manufactured: **S/N:**

Body Procedure:

Patient information					Patient dose and related parameters			
Patient no.	Gender (F/M)	Age (Year)	Weight (kg)	Height (cm)	Flu. time (min)	Air KERMA (mGy)	KAP ($Gy.cm^2$)	No. of images
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Table A. 2 Data collection for neuro-interventional procedure

Angiographic equipment:

Model: ☐ Single plane ☐ Biplane

Manufactured: S/N:

Body Procedure:

Patient information					Patient dose and related parameters											
					2D		3D			Cone Beam CT			Total			
Patient no.	Gender (F/M)	Age (Year)	Weight (kg)	Height (cm)	Air KERMA (mGy)	KAP (Gy.cm^2)	No. of vessels	Air KERMA (mGy)	KAP (Gy.cm^2)	No. of runs	Air KERMA (mGy)	KAP (Gy.cm^2)	Flu. time (min)	Air KERMA (mGy)	KAP (Gy.cm^2)	No. of images
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																

APPENDIX B EQUIPMENT PERFORMANCE FOR ANGIOGRAPHY SYSTEM

Equipment performance for angiography system

Report of angiography system performance

Perform QC of angiographic equipment using IAEA TRS 457 (11) and AAPM Report no.58 (12)

Hospital: King Chulalongkorn Memorial Hospital

Room: Intervention 1

Manufacturer: Canon (Toshiba) Infinix, installed 2014

Model number: DSRX-T7345GFS

Serial number: 18B438RU

Date: 18 April 2020

Test performed by Miss Kornkamol Prajamchuea

List of QC test	Result
1.1 Dose assessment	Pass
1.2 Automatic Brightness Control (ABC) Test	Pass
1.3 Maximum dose rate assessment	Pass
1.4 Field size assessment	Pass
1.5 Table attenuation	Pass
1.6 Half Value Layer (HVL)	Pass
1.7 Image quality assessment	Pass

1.1 Dose assessment

Table B. 1. 1 Dose assessment of Canon (Toshiba) Infinix

Single Plane										
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Patient entrance surface Air KERMA at 60 cm (µGy/s)	Image Intensifier entrance surface Air KERMA (µGy/s)	Patient entrance surface Air KERMA at 60 cm (including backscatter 1.3) (µGy/s)	Phantom
Fluoro	DSA 3f/s (low)	10	0.2 mm Cu	40	80	74	265.80	50.01	345.54	PMMA slab phantom 20 cm.+ 1 mm Cu
				30	80	94	301.30	9.26	391.69	
				20	80	149	499.60	13.03	649.48	
				15	81	195	931.30	15.20	1210.69	
				10.75	90	176	1393	20	1810.90	
				8.25	104	154	2109	23.46	2741.70	

1.2 Automatic Brightness Control (ABC) Test

Table B. 1. 2 Automatic Brightness Control (ABC) test of Canon (Toshiba) Infinix

Single Plane								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Added filtration (mm Cu)	Entrance surface Air KERMA (µGy/s)
Fluoro	DSA 3f/s (low)	10	0.2 mm Cu	40	67	10	1 mm Cu	6.3
					77	10	2 mm Cu	8.94
					80	13	3 mm Cu	13.56
					80	20	4 mm Cu	21.83

1.3 Maximum dose rate assessment

Table B. 1. 3 Maximum dose rate assessment of Canon (Toshiba) Infinix

Single Plane								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	PMMA slab Phantom 20cm + added fitration (mm Cu)	Patient entrance surface dose rate at 60 cm (µGy/s)
Fluoro	DSA 3f/s (low)	10	0.2 mm Cu	40	80	69	1mm Cu	243.7
					80	110	2mm Cu	355.6
					80	166	3mm Cu	632.5
					84	189	4mm Cu	1214.1

Comment: the maximum exposure shall not exceed 20 Gy/min for high level fluoroscopic mode (IAEA recommendation).

1.4 Field size assessment

Table B. 1. 4 Field size assessment of all radiation fields

Single Plane				
Mode	Submode/ image quality	Field size (cm)	Horizontal size (cm)	Vertical size (cm)
Fluoro	DSA 3f/s (low)	40	32	24.48
		30	28.30	28.40
		20	18.60	18.40
		15	14	13.80
		10.75	10	10
		8.25	7.70	7.80

Comment: 40 cm. field size is rectangular shape, but all are square shape.

1.5 Table attenuation

Table B. 1. 5 Table attenuation of Canon (Toshiba) Infinix

Single Plane				
Mode	Submode/ image quality	Dose rate (µGy/s)	Table Attenuation (%)	Absorber
C-arm with table	DSA 3f/s (low)	6.75	5.33	1 mm Cu
C-arm without table	DSA 3f/s (low)	6.39		

Comment: table attenuation should be less than 10%

1.6 Half Value Layer (HVL)

Table B. 1. 6 Half Value Layer (HVL) of Canon (Toshiba) Infinix

Single Plane				
Submode/ image quality	kV	mA	Dose rate (µGy/s)	HVL (mm)
DSA 3f/s (low)	80	20	21.83	5

1.7 Image quality assessment

Table B .1. 7 Image quality assessment of Canon (Toshiba) Infinix

Single Plane							
Mode	Submode/ Image quality	Automatic added filtration	Field size (cm)	kV	mA	High contrast resolution (lp/mm)	Low contrast resolution (mm)
Fluoro	DSA 3f/s (low)	0.2 mm Cu	40	53	10	2.80	0.045
			30	54	10	2.50	0.039
			20	60	10	1.60	0.045
			15	64	10	1.25	0.045
			10.75	68	10	1.25	0
			8.25	71	10	1.25	0

Comment: for high contrast resolution, requirement resolution tolerances should be 0.5-5.0 lp/mm. For low contrast resolution, requirement resolution tolerances should be visualized of +/- 5% compare with manufacturer.

Hospital: King Chulalongkorn Memorial Hospital

Room: Intervention 2

Manufacturer: Siemens Artis Zee Single plane, installed 2011

Model number: 10144184

Serial number: 696171972

Date: 18 April 2020

Test performed by Miss Kornkamol Prajamchuea

List of QC test	Result
2.1 Dose assessment	Pass
2.2 Automatic Brightness Control (ABC) Test	Pass
2.3 Maximum dose rate assessment	Pass
2.4 Field size assessment	Pass
2.5 Table attenuation	Pass
2.6 Half Value Layer (HVL)	Pass
2.7 Image quality assessment	Pass

2.1 Dose assessment

Table B. 2. 1 Dose assessment of Siemens Artis Zee single plane

Single Plane										
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Patient entrance surface Air KERMA at 60 cm (µGy/s)	Image Intensifier entrance surface Air KERMA (µGy/s)	Patient entrance surface Air KERMA at 60 cm (including backscatter 1.3) (µGy/s)	Phantom
Fluoro	DSA 3f/s (low)	7.50	1.5 mm Al	48	67.70	210.80	173.80	10.48	225.94	PMMA slab phantom 20 cm.+1 mm Cu
				42	67.70	238.80	183.10	6.15	238.03	
				32	71.30	149.50	319.80	7.65	415.74	
				22	79.80	245.80	1325	8.61	1722.50	
				16	91.10	228	2594	39.02	3372.20	
				11	117	176.90	3525	53.29	4582.50	

2.2 Automatic Brightness Control (ABC) Test

Table B. 2. 2 Automatic Brightness Control (ABC) test of Siemens Artis Zee single plane

Single Plane								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Added filtration (mm Cu)	Entrance surface Air KERMA (μGy/s)
Fluoro	DSA 3f/s (Normal)	7.5	1.5 mm Al	48	61.70	13.30	1 mm Cu	3.04
					67.70	14.80	2 mm Cu	6.13
					67.70	42.30	3 mm Cu	12.61
					67.70	90.30	4 mm Cu	26.61

Comment: the maximum exposure shall not exceed 20 Gy/min for high level fluoroscopic mode (IAEA recommendation).

2.3 Maximum dose rate assessment

Table B. 2. 3 Maximum dose rate assessment of Siemens Artis Zee single plane

Single Plane								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	PMMA slab Phantom 20cm + added filtration (mm Cu)	Patient entrance surface dose rate at 60 cm (μGy/s)
Fluoro	DSA 3f/s (low)	7.50	1.5 mm Al	48	67.70	209.20	1mm Cu	165.10
					73.50	242.50	2mm Cu	267.60
					75.90	242.90	3mm Cu	634.30
					77	245.20	4mm Cu	1279

2.4 Field size assessment

Table B. 2. 4 Field size assessment of all radiation fields

Single Plane				
Mode	Submode/ image quality	Field size (cm)	Horizontal size (cm)	Vertical size (cm)
Fluoro	DSA Body 3f/s (Normal)	48	33.10	24.62
		42	25	20
		32	20.30	21.50
		22	14.40	14.30
		16	10.20	10.10
		11	7	7.30

Comment: 48 cm. field size is rectangular shape, but all are square shape.

2.5 Table attenuation

Table B. 2. 5 Table attenuation of Siemens Artis Zee single plane

Single Plane				
Mode	Submode/ image quality	Dose rate (µGy/s)	Table Attenuation (%)	Absorber
C-arm with table	DSA Body 3f/s (Normal)	3.39	4.72	1 mm Cu
C-arm without table	DSA Body 3f/s (Normal)	3.23		

Comment: table attenuation should be less than 10%

2.6 Half Value Layer (HVL)

Table B. 2. 6 Half Value Layer (HVL) of Siemens Artis Zee single plane

Single Plane				
Submode/ image quality	kV	mA	Dose rate (µGy/s)	HVL (mm)
DSA Body 3f/s (Normal)	80	246	1325	5.60

2.7 Image quality assessment

Table B. 2. 7 Image quality assessment of Siemens Artis Zee single plane

Single Plane							
Mode	Submode /Image quality	Automatic added filtration	Field size (cm)	kV	mA	High contrast resolution (lp/mm)	Low contrast resolution (mm)
Fluoro	DSA Body 3f/s (Normal)	1.5 mm Al	48	55.40	13.20	2.50	0.045
			42	55	13.40	2.24	0.053
			32	57.80	13.60	1.60	0.053
			22	63	13.50	1.25	0.045
			16	67.70	15.50	1.12	0.045
			11	67.70	27.10	1	0

Comment: for high contrast resolution, requirement resolution tolerances should be 0.5-5.0 lp/mm. For low contrast resolution, requirement resolution tolerances should be visualized of +/- 5% compare with manufacturer.

Hospital: King Chulalongkorn Memorial Hospital

Room: Intervention 4

Manufacturer: Siemens Artis Zee Biplane, installed 2015

Model number: 10144184

Serial number: 695451871

Date: 16 April 2020

Test performed by Miss Kornkamol Prajamchuea

List of QC test	Result
3.1 Dose assessment	Pass
3.2 Automatic Brightness Control (ABC) Test	Pass
3.3 Maximum dose rate assessment	Pass
3.4 Field size assessment	Pass
3.5 Table attenuation	Fail
3.6 Half Value Layer (HVL)	Pass
3.7 Image quality assessment	Pass

3.1 Dose assessment

Table B. 3. 1 Dose assessment of plane A and B of Siemens Artis Zee biplane

Plane A										
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Patient entrance surface Air KERMA at 60 cm (µGy/s)	Image Intensifier entrance surface Air KERMA (µGy/s)	Patient entrance surface Air KERMA at 60 cm (including backscatter 1.3) (µGy/s)	Phantom
Fluoro	DSA Extremity 2019 2f/s (Normal)	3	1.5 mm Al	48	62	232	130	7.90	169	PMMA slab phantom 20 cm.+ 1 mm Cu
				42	89.85	418	200.10	7.27	260.13	
				32	89	499	276.90	7.93	359.97	
				22	108.40	556	581.30	10.35	755.69	
				16	128.50	432	1062	21.32	1380.60	
				11	136.40	439	1315	26.39	1709.50	

Plane B										
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Patient entrance surface Air KERMA at 60 cm (µGy/s)	Image Intensifier entrance surface Air KERMA (µGy/s)	Patient entrance surface Air KERMA at 60 cm (including backscatter 1.3) (µGy/s)	Phantom
Fluoro	DSA Extremity 2019 2f/s (Normal)	3	1.5 mm Al	48	73	108.55	94.38	4.82	122.69	PMMA slab phantom 20 cm.+ 1 mm Cu
				42	73	151.20	105	4.47	136.50	
				32	73	239.49	137	3.76	178.10	
				22	74	304.94	423	4.02	549.90	
				16	121	240.75	880.10	18	1144.13	
				11	146.51	136.48	1591.10	26.44	2068.43	

3.2 Automatic Brightness Control (ABC) Test

Table B. 3. 2 Automatic Brightness Control (ABC) test of plane A and B of Siemens Artis Zee biplane

Plane A								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Added filtration (mm Cu)	Entrance surface Air KERMA (µGy/s)
Fluoro	DSA Extremity 2019 2f/s (Normal)	3	1.5 mm Al	48	65.60	13.00	1mm Cu	1.81
					69.40	19.50	2mm Cu	3.16
					69.40	40.70	3mm Cu	6.20
					69.40	90.00	4mm Cu	11.89

Plane B								
mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Added filtration (mm Cu)	Entrance surface Air KERMA (µGy/s)
Fluoro	DSA Extremity 2019 2f/s (Normal)	3	1.5 mm Al	48	64.2	14.3	1 mm Cu	3.741
					69.4	17.3	2 mm Cu	3.2
					69.4	34.1	3 mm Cu	5.52
					69.4	80.1	4 mm Cu	11.47

Comment: the maximum exposure shall not exceed 20 Gy/min for high level fluoroscopic mode (IAEA recommendation).

3.3 Maximum dose rate assessment

Table B. 3. 3 Maximum dose rate assessment of plane A and B of Siemens Artis Zee biplane

Plane A								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	PMMA slab phantom 20cm + added filtration (mm Cu)	Patient entrance surface dose rate at 60 cm (µGy/s)
Fluoro	DSA Extremity 2019 2f/s (Normal)	3	1.5 mm Al	48	73	147.80	1mm Cu	125.70
					76.60	236.50	2mm Cu	209.40
					82.70	240	3mm Cu	276.10
					88.80	237.70	4mm Cu	311.40

Plane B								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	PMMA slab Phantom 20cm + added filtration (mm Cu)	Patient entrance surface dose rate at 60 cm (µGy/s)
Fluoro	DSA Extremity 2019 2f/s (Normal)	3	1.5 mm Al	48	73	109.6	1mm Cu	127.1
					73.8	214.7	2mm Cu	218.8
					80	231.9	3mm Cu	304.9
					85.3	231.9	4mm Cu	354

3.4 Field size assessment

Table B. 3. 4 Field size assessment of all radiation fields

Plane A				
Mode	Submode/ image quality	Field size (cm)	Horizontal size (cm)	Vertical size (cm)
Fluoro	DSA Extremity 2019 2f/s (Normal)	48	32.52	25.94
		42	19.20	20.50
		32	14.70	15
		22	10.70	10.40
		16	7.40	7.40
		11	5.20	5.20

Plane B				
Mode	Submode/ image quality	Field size (cm)	Horizontal size (cm)	Vertical size (cm)
Fluoro	DSA Extremity 2019 2f/s (Normal)	48	20.7	17
		42	16.7	17
		32	13.8	13.5
		22	9.1	9
		16	7	6.8
		11	4.6	4.6

Comment: 48 cm. field size is rectangular shape, but all are square shape.

3.5 Table attenuation

Table B. 3. 5 Table attenuation of plane A of Siemens Artis Zee biplane

Plane A				
Mode	Submode/ image quality	Dose rate (µGy/s)	Table Attenuation (%)	Absorber
C-arm with table	DSA Extremity 2019 2f/s (Normal)	7.02	38.47	1 mm Cu
C-arm without table	DSA Extremity 2019 2f/s (Normal)	4.32		

Comment: table attenuation should be less than 10%

3.6 Half Value Layer (HVL)

Table B. 3. 6 Half Value Layer (HVL) of plane A and B of Siemens Artis Zee biplane

Plane A				
Submode/ image quality	kV	mA	Dose rate (µGy/s)	HVL (mm)
DSA Extremity 2019 2f/s (Normal)	80	499	276.9	6.6

Plane B				
Submode/ image quality	kV	mA	Dose rate (µGy/s)	HVL (mm)
DSA Extremity 2019 2f/s (Normal)	80	252.58	194.20	7

3.7 Image quality assessment

Table B. 3. 7 Image quality assessment of plane A and B of Siemens Artis Zee biplane

Plane A							
Mode	Submode /Image quality	Automatic added filtration	Field size (cm)	kV	mA	High contrast resolution (lp/mm)	Low contrast resolution (mm)
Fluoro	DSA Extremity 2019 2f/s (Normal)	1.5 mm Al	48	56	0.05	2.24	0.045
			42	55.90	0.05	2	0.053
			32	59	0.05	1.40	0.045
			22	67	0.05	1.25	0.075
			16	69.40	0.16	1.12	0
			11	69	0.10	1	0

Plane B							
Mode	Submode /Image quality	Automatic added filtration	Field size (cm)	kV	mA	High contrast resolution (lp/mm)	Low contrast resolution (mm)
Fluoro	DSA Extremity 2019 2f/s (Normal)	0.8 mm Al	48	65.2	0.051	2.8	0.053
			42	65	0.048	2.24	0.075
			32	68	0.048	1.6	0.075
			22	69	0.095	1.25	0.053
			16	69	0.17	1.12	0.053
			11	69	0.26	1.12	0

Comment: for high contrast resolution, requirement resolution tolerances should be 0.5-5.0 lp/mm. For low contrast resolution, requirement resolution Tolerances should be visualized of +/- 5% compare with manufacturer.

Hospital: King Chulalongkorn Memorial Hospital

Room: Intervention 5

Manufacturer: Philips Allura Clarity Xper FD20/15, installed 2015

Model number: 9890 000 86501

Serial number: 9890 000 86501

Date: 15 April 2020

Test performed by Miss Kornkamol Prajamchuea

List of QC test		Result
4.1	Dose assessment	Pass
4.2	Automatic Brightness Control (ABC) Test	Pass
4.3	Maximum dose rate assessment	Pass
4.4	Field size assessment	Pass
4.5	Table attenuation	Fail
4.6	Half Value Layer (HVL)	Pass
4.7	Image quality assessment	Pass

4.1 Dose assessment

Table B. 4. 1 Dose assessment of plane A and B of Philips Allura Clarity Xper FD20/15

Plane A										
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Patient entrance surface Air KERMA at 60 cm (µGy/s)	Image Intensifier entrance surface Air KERMA (µGy/s)	Patient entrance surface Air KERMA at 60 cm (including backscatter 1.3) (µGy/s)	Phantom
Fluoro	Cerebral 3fps 50%dose (Normal)	12.5	0.4 mmCu + 1.0 mmAl	48	78	16	124.80	7.94	162.24	PMMA slab phantom 20 cm.+ 1 mm Cu
				42	78	22	177.40	9.77	230.62	
				37	78	26	198.80	10.50	258.44	
				31	78	36	236.60	11.66	307.58	
				22	80	58	242.30	8.71	314.99	
				19	101	46	238.40	7.61	309.92	
				15	114	41	239.80	6.40	311.74	

Plane B										
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	kV	mA	Patient entrance surface Air KERMA at 60 cm (µGy/s)	Image Intensifier entrance surface Air KERMA (µGy/s)	Patient entrance surface Air KERMA at 60 cm (including backscatter 1.3) (µGy/s)	Phantom
Fluoro	Cerebral 3fps 50%dose (Normal)	12.5	0.4 mmCu + 1.0 mmAl	39	101.63	17	138.10	11.30	179.53	PMMA slab phantom 20 cm.+ 1 mm Cu
				37	107.43	18	175.10	11.27	227.63	
				31	127.27	27	215.30	13	279.89	
				27	141.90	47	278.90	12.44	362.57	
				22	139.74	42	282.40	10.27	367.12	
				19	138.57	37	281.40	9.58	365.82	
				15	134.90	32	288.30	8.04	374.79	

4.2 Automatic Brightness Control (ABC) Test

Table B. 4. 2 Automatic Brightness Control (ABC) test of plane A and B of Philips Allura Clarity Xper FD20/15

Plane A								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration (mm Cu)	Field size (cm)	kV	mA	Added filtration (mm Cu)	Entrance surface Air KERMA (µGy/s)
Fluoro	Cerebral 3fps 50%dose (Normal)	12.5	0.4 mmCu + 1.0 mmAl	48	63	0.25	1 mm Cu	11.60
					78	0.25	2 mm Cu	25.92
					78	0.50	3 mm Cu	44.08
					78	1	4 mm Cu	64.31

Plane B								
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration (mm Cu)	Field size (cm)	kV	mA	Added filtration (mm Cu)	Entrance surface Air KERMA (µGy/s)
Fluoro	Cerebral 3fps 50%dose (Normal)	12.5	0.4 mmCu + 1.0 mmAl	39	64	1.50	1 mm Cu	19.36
					68	2.40	2 mm Cu	33.14
					71	3.20	3 mm Cu	51.89
					76	3.40	4 mm Cu	72.44

Comment: the maximum exposure shall not exceed 20 Gy/min for high level fluoroscopic mode (IAEA recommendation).

4.3 Maximum dose rate assessment

Table B. 4. 3 Maximum dose rate assessment of plane A and B of Philips Allura Clarity Xper FD20/15

Plane A						
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	PMMA slab Phantom 20 cm + added filtration (mm Cu)	Patient entrance surface dose rate at 60 cm (µGy/s)
Fluoro	Cerebral 3fps 50%dose (Normal)	12.5	0.4 mmCu + 1.0 mmAl	48	1 mm Cu	124.80
					2 mm Cu	149.50
					3 mm Cu	230.80
					4 mm Cu	245.10

Plane B						
Mode	Submode /Image quality	Pulse rate (pulse/s)	Automatic added filtration	Field size (cm)	PMMA slab phantom 20 cm + added filtration (mm Cu)	Patient entrance surface dose rate at 60 cm (µGy/s)
Fluoro	Cerebral 3fps 50%dose (Normal)	12.5	0.4 mmCu + 1.0 mmAl	39	1 mm Cu	172.60
					2 mm Cu	228.80
					3 mm Cu	261.30
					4 mm Cu	258.60

4.4 Field size assessment

Table B. 4. 4 Field size assessment of all radiation fields

Plane A				
Mode	Submode/ image quality	Field size (cm)	Horizontal size (cm)	Vertical size (cm)
Fluoro	Cerebral 3fps 50%dose (Normal)	48	47.60	47.60
		42	39.70	39.10
		37	35.10	35.40
		31	28.10	29.80
		22	21.50	19.60
		19	18.50	18.50
		15	15.30	15.50

Plane B				
Mode	Submode/ image quality	Field size (cm)	Horizontal size (cm)	Vertical size (cm)
Fluoro	Cerebral 3fps 50%dose (Normal)	39	33.48	31.56
		37	24.6	26.7
		31	21.7	20
		27	18.1	17.2
		22	15.5	15
		19	12	13
		15	10.2	10.8

4.5 Table attenuation

Table B. 4. 5 Table attenuation of plane A of Philips Allura Clarity Xper FD20/15

Plane A				
Mode	Submode/ image quality	Dose rate (µGy/s)	Table Attenuation (%)	Absorber
C-arm with table	Cerebral 3fps 50%dose (Normal)	43.51	15.38	1 mm Cu
C-arm without table	Cerebral 3fps 50%dose (Normal)	36.82		

Comment: table attenuation should be less than 10%

4.6 Half Value Layer (HVL)

Table B. 4. 6 Half Value Layer (HVL) of single plane of plane A and B of Philips Allura Clarity Xper FD20/15

Plane A				
Submode/ image quality	kV	mA	Dose rate (µGy/s)	HVL (mm)
Cerebral 3fps 50%dose (Normal)	80	58	242.30	7.20

Plane B				
Submode/ image quality	kV	mA	Dose rate (µGy/s)	HVL (mm)
Cerebral 3fps 50%dose (Normal)	80	52	240.10	7

4.7 Image quality assessment

Table B. 4. 7 Image quality assessment of plane A and B of Philips Allura Clarity Xper FD20/15

Plane A							
Mode	Submode /Image quality	Automatic added filtration	Field size (cm)	kV	mA	High contrast resolution (lp/mm)	Low contrast resolution (mm)
Fluoro	Cerebral 3fps 50%dose (Normal)	0.4 mmCu + 1.0 mmAl	48	43	1	2	0.045
			42	46	1	1.80	0.045
			37	48	1	1.60	0.039
			31	52	1	1.12	0.045
			22	56	1	0.90	0.045
			19	58	1	0.80	0
			15	61	1	0.80	0

Plane B							
Mode	Submode /Image quality	Automatic added filtration	Field size (cm)	kV	mA	High contrast resolution (lp/mm)	Low contrast resolution (mm)
Fluoro	Cerebral 3fps 50%dose (Normal)	0.4 mmCu + 1.0 mmAl	39	47	1	2.50	0.045
			37	48	1	2.24	0.045
			31	51	1	1.60	0.039
			27	55	1	1.40	0.027
			22	58	1	1.40	0.039
			19	64	1	1.40	0.045
			15	64	1	1	0

Comment: for high contrast resolution, requirement resolution tolerances should be 0.5-5.0 lp/mm. For low contrast resolution, requirement resolution tolerances should be visualized of +/- 5% compare with manufacturer

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VITA

NAME	Kornkamol Prajamchuea
DATE OF BIRTH	7 Febuary 1994
PLACE OF BIRTH	Samutprakarn Province
INSTITUTIONS ATTENDED	Bachelor of Science, Radiological Technology program, Department of Radiological Technology, Faculty of Medical Technology, Mahidol University, Nakhon Pathom, Thailand
HOME ADDRESS	199/387 Notting hill Sukhumvit 105 Lasalle Rd, Bangna, Bangkok 10260
PUBLICATION	Prajamchuea K, Krisanachinda A. The Study of Local Diagnostic Reference Levels at Unit of Vascular and Interventional Radiology, King Chulalongkorn Memorial Hospital in Proceedings of 20th Asia-Oceania Congress on Medical Physics (AOCMP) - 18th South-East Asia Congress of Medical Physics (SEACOMP) - 12th Annual Meeting of Thai Medical Physicist Society (TMPS), Phuket, Thailand, 2020
AWARD RECEIVED	Silver Award of Cypos TPI 089, JRC 2021, The Annual Meeting of the Japanese Radiological Society, The 77th Annual Meeting of The Japanese Society of Radiological Technology (JSRT), 16-18 April 2021, Yokohama, Japan