การหาปริมาณรังสีและคุณภาพของภาพในการถ่ายภาพรังสีทั่วไปด้วยระบบคอมพิวเตอร์ เปรียบเทียบผลการศึกษาก่อน และหลังการอบรม

นางสาวสุณี ล้ำเลิศเดชา

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PATIENT RADIATION DOSE AND IMAGE QUALITY IN SIMPLE RADIOGRAPHIC PROJECTIONS USING COMPUTED RADIOGRAPHY (CR) SYSTEM: COMPARISON THE RESULTS BETWEEN BEFORE AND AFTER THE TRAINING

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science Program in Medical Imaging
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Thesis Title	PATIENT RADIATION DOSE AND IMAGE QUALITY IN SIMPLE RADIOGRAPHIC PROJECTIONS USING COMPUTED RADIOGRAPHY (CR) SYSTEM: COMPARISON THE RESULTS BETWEEN BEFORE AND AFTER THE TRAINING
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สุณี ล้ำเลิศเดชา:การหาปริมาณรังสีและคุณภาพของภาพในการถ่ายภาพรังสีทั่วไปด้วยระบบคอมพิวเตอร์เปรียบเทียบผลการศึกษาก่อน และหลังการอบรม.
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อ.ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.ดร.อัญชลี กฤษณจินดา, 94 หน้า

วัตถุประสงค์ของงานวิจัยนี้เพื่อที่จะหาปริมาณรังสีที่ผู้ป่วยได้รับจากการตรวจทางคลินิกในการถ่ายภาพรังสีด้วยระบบคอมพิวเตอร์ โดยคุณภาพของภาพต้องเพียงพอต่อการวินิจฉัย และลดการถ่ายภาพซ้ำ ข้อมูลเก็บจากผู้ป่วย 458 ราย จากการถ่ายภาพรังสีสองห้อง ของโรงพยาบาลราชวิถี กระทรวงสาธารณสุข ในการถ่ายภาพรังสี 7 ท่า ได้แก่ภาพทรวงอกด้านหลัง ภาพช่องท้องด้านหน้า ภาพกระดูกคอด้านหน้า ภาพกระดูกสันหลังระดับเอวด้านหน้าและด้านข้าง และภาพกะโหลกศีรษะด้านหลังและด้านข้าง เพื่อใช้ในการคำนวณปริมาณรังสี และประเมินคุณภาพของภาพโดยรังสีแพทย์ เป็นระดับต่างๆ ระดับเอยอมรับได้ดี ระดับบีรับได้แต่มีความเห็น และระดับซีรับไม่ได้ การคำนวณปริมาณรังสีในผู้ป่วยใช้ปริมาณรังสีที่วัดในอากาศ เทคนิคที่ใช้ในการถ่ายภาพ ข้อมูลทั่วไปของผู้ป่วย และค่ารังสีสะท้อน

ผลการศึกษาปริมาณรังสีก่อนและหลังการอบรม ในหน่วยมิลลิเกรย์ จากห้องหมายเลข 4 ดังนี้ภาพทรวงอกด้านหลังมีค่า 0.23/0.17 ภาพช่องท้องด้านหน้ามีค่า 3.34/3.03 ภาพกระดูกคอด้านหน้ามีค่า 0.32/0.29 ภาพกระดูกสันหลังระดับเอวด้านหน้าและด้านข้างมีค่า 3.02/2.74 และ 8.93/8.32 และภาพกะโหลกศีรษะด้านหลังและด้านข้างมีค่า 1.94/1.74 และ 1.71/1.49 จากห้องอีเอ็มเอสดังนี้ ภาพทรวงอกด้านหลังมีค่า 0.36/0.25 ภาพช่องท้องด้านหน้ามีค่า 2.84/2.81 ภาพกระดูกคอด้านหน้ามีค่า 0.34/0.33 ภาพกระดูกสันหลังระดับเอวด้านหน้า และด้านข้างมีค่า 2.20/1.96 และ 8.79/7.90 และภาพกะโหลกศีรษะด้านหลังและด้านข้างมีค่า 1.57/1.26 และ 1.58/1.20 ค่าปริมาณรังสีเฉลี่ยทุกค่า มีค่าน้อยกว่าค่าปริมาณรังสีอ้างอิง ปริมาณรังสีที่ลดลงแต่ไม่มีนัยสำคัญทางสถิติได้แก่ ภาพช่องท้องด้านหน้า ภาพกระดูกคอด้านหน้า ภาพกระดูกสันหลังระดับเอวด้านหน้าและด้านข้าง และภาพกะโหลกศีรษะด้านหลังและด้านข้าง แต่มีนัยยะสำคัญทางสถิติได้แก่ภาพทรวงอกด้านหลังจากห้องหมายเลข 4 ปริมาณรังสีที่ลดลงไม่มีนัยสำคัญทางสถิติได้แก่ ภาพช่องท้องด้านหน้า ภาพกระดูกสันหลังระดับเอวด้านหน้า และภาพกะโหลกศีรษะด้านหลังและด้านข้าง แต่มีนัยยะสำคัญทางสถิติได้แก่ภาพทรวงอกด้านหลัง ภาพกระดูกคอด้านหน้า ภาพกระดูกสันหลังระดับเอวด้านข้างจากห้องอีเอ็มเอส ส่วนคุณภาพของภาพต่ำมาจากสาเหตุ การจัดท่าผู้ป่วย ภาพรังสีดำหรือขาวไป และภาพที่พบวัตถุแปลกปลอม อัตราการถ่ายฟิล์มซ้ำจากห้องเอกซเรย์ทั้งสองห้อง ก่อนและหลังการอบรม ห้องเอกซเรย์หมายเลข 4 มี 51 ภาพหรือ 3.4%จาก 1,488 ภาพ และ 66 ภาพหรือ 2.5%จาก 2,668 ภาพ และห้องอีเอ็มเอสมี 75 ภาพหรือ 2.7%จาก 2,751 ภาพ และ 72 ภาพหรือ 2.47%จาก 2,905 ภาพ การถ่ายภาพซ้ำมาจากสาเหตุการจัดท่ามากที่สุด ปริมาณรังสีที่คำนวณได้ สามารถนำมาใช้ในการกำหนดปริมาณรังสีอ้างอิงของประเทศได้

ภาควิชา รังสีวิทยา ลายมือชื่อนิสิต สุณี ล้ำเลิศเดชา

สาขาวิชา ฉายาเวชศาสตร์ ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก

ปีการศึกษา 2551

5074843330 : MAJOR MEDICAL IMAGING

KEYWORDS : COMPUTED RADIOGRAPHY (CR)/ KERMA/ ENTRANCE SKIN DOSE (ESD)/ DIAGNOSTIC REFERENCE LEVELS (DRLs) / IMAGE QUALITY

SUNEE LUMLERTDACHA : PATIENT RADIATION DOSE AND IMAGE QUALITY IN SIMPLE RADIOGRAPHIC PROJECTIONS USING COMPUTED RADIOGRAPHY (CR) SYSTEM: COMPARISON THE RESULTS BETWEEN BEFORE AND AFTER THE TRAINING. ADVISOR : ASSOC. PROF. ANCHALI KRISANACHINDA, Ph.D.,

94 pp.

The purpose of this study is to determine the patient dose in clinical setting from the CR system while maintaining the image quality and the retake rate reduction. The data were collected from patients examined at two X-ray rooms, No.4 and EMS, in five routine types of seven projections. Those were chest (PA), abdomen (AP), cervical spine (AP), lumbar spine (AP/LAT), and skull (PA/LAT) at Rajavithi Hospital, Ministry of Public Health, Bangkok Thailand. 458 digital images were collected for the purpose of the dose determination and image quality over a period of one month. The entrance surface dose (ESD) was calculated using the data of the entrance surface air kerma, ESAK, the radiographic technique data, the patient data and back scatter factor for a selected group of patients in the period of before and after the training program. Image quality was evaluated by two radiologists as Grade A (clearly accept), B (accept with some remarks) and C (reject).

The results show that the mean ESD of before and after training in mGy, from Room No.4 of chest (PA) was 0.23/0.17, abdomen (AP) 3.34/3.03, cervical-spine (AP) 0.32/0.29, lumbar-spine (AP/LAT) 3.02/2.72, 8.93/8.32 and skull (PA/LAT) 1.94/1.74, 1.71/1.49 respectively. From Room EMS of chest (PA) was 0.36/0.25, abdomen (AP) 2.84/2.81, cervical-spine (AP) 0.34/0.33, lumbar-spine (AP/LAT) 2.20/1.96, 8.79/7.90 and skull (PA/LAT) 1.57/1.26, 1.58/1.20 respectively. The mean ESD of all projections is less than the international guidance level. For Room No.4, there was no statistically significant in patient dose after training for abdomen (AP), cervical spine (AP) lumbar spine (AP/LAT), and skull (PA/LAT) examinations ($p>0.05$).Whereas for chest (PA) has statistically significant improvement ($p<0.05$). For Room EMS, there was no statistically significant in patient dose after training for abdomen (AP), lumbar spine (AP), and skull (PA/LAT) examinations ($p>0.05$).Whereas for chest (PA), cervical spine (AP) and lumbar spine (LAT) show statistically significant to patient dose ($p<0.05$). The poor image quality caused by the patient positioning, over-under exposure, and image artifact. The reject analysis before and after training was 51/1,488 images or 3.4% and 66/2,668 images or 2.5% from Room No.4, and 75/2,751 images or 2.7% and 72/ 2,905 images or 2.5% from Room EMS. The cause of retake was mainly from patient positioning. The data are useful for the formation of national guidance levels as recommended by IAEA.

Department : Radiology Student's Signature Sunee Lumlertdacha

Field of Study : Medical Imaging Advisor's Signature Anchali Krisanachinda

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LIST OF ABBREVIATIONS

Abbreviation	Terms
≈	Approximate
AAPM	American Association of Physics in Medicine
ADC	Analog to Digital Converter
Al	Aluminium
AP	Anteroposterior
BaFBr	Barium Fluorobromide
BMI	Body Mass Index
BSF	Back Scatter Factor
CCD	Charge Couple Device
cd/m^2	Candle per square meter
cm	Centimeter
CR	Computed Radiography
CT	Computed Tomography
DR	Digital Radiography
DRLs	Dose Reference Levels
DQE	Detective Quantum Efficiency
e.g.	For example
ESAK	Entrance Skin Air Kerma
Eu^{+2}	Divalent Europium Atom
eV	Electron volt
ESD	Entrance Skin Dose
FCD	Focal Chamber Distance
FFD	Focal Film Distance
FSD	Focal Skin Distance

Abbreviation	Terms
IAEA	International Atomic Energy Agency
HVL	Half Value Layer
ICRP	International Commission on Radiological Protection
IP	Image Plate
kVp	Kilovoltage peak
Kg	Kilogram
LAT	Lateral
LUT	Look –Up-Table
mA	Milliampere
mAs	Milliampere second
MCQ	Multiple Choice Question
mGy	Milligray
mm	Millimeter
µ	Micro
mR	Milliroentgen
MRI	Magnetic Resonance Imaging
mSv	Milli-Sievert
mm-yy	Month-Year
MTF	Modulation Transfer Function
OD	Optical Density
PA	Posteroanterior
PACS	Picture Archiving and Communication System
PMT	Photo Multiplier Tube
PSL	Photostimulated Luminescence

Abbreviation	**Terms**
PSP	Photostimulable Phosphor
QA	Quality Assurance
QC	Quality Control
SNR	Signal to Noise Ratio

CHAPTER I

INTRODUCTION

1.1 Background and rationale

The use of x-rays in the medical diagnosis of developing countries results in the largest exposure to ionization radiation from man-made sources.[1]For many decades, conventional screen-film system has been used in most department of radiology. This system has the narrow range of film response, cassettes manipulation, delayed display, storage and retrieval problems. In recent years there has been a very rapid introduction of a new imaging technology in diagnostic radiology, computed radiography (CR) system. Existing radiological equipments have been used with CR cassette to create radiographic image. CR has become a major digital imaging modality in a modern radiological department. The other imaging modality such as Computed tomography (CT) and magnetic resonance imaging (MRI) are intrinsic digital, ultrasound and nuclear medicine imaging made the change to digital imaging from their analog ancestries in the 1970s. Thus radiography is really the last modality to make the transition to digital acquisition.

CR system changes workflow from the conventional way of using film/screen by employing photostimulable phosphor plate technology. [2] In CR, the imaging plate containing storage phosphor is inserted in a cassette similar to a screen-film system, exposed to x-rays, and the signal trapped by the plate read by the scanning of a laser beam. A photomultiplier tube then enhances the signal coming from the light guide. [3, 4] Many manufacturers provide variety of digital imaging solutions based on detectors and readout technologies. Digital detectors allow implementation of a fully digital picture archiving and communication system (PACS), in which images are stored digitally and available at anytime. Image distribution in hospitals can now be achieved electronically by means of web-based technology with no risk of losing images. Other advantages of digital radiography include higher patient throughput, and the greater dynamic range of digital detectors with possible reduction of radiation exposure to the patient. The radiologists, radiological technologists, and physicists should be familiar with the technical principles, image quality criteria, and radiation exposure issues associated with various digital radiography systems currently available.

CR has become a major diagnostic digital imaging modality at Department of Radiology, Rajavithi Hospital, Ministry of Public Heath, since November 2006. Successful shifting from conventional to fully digitized radiological department requires skillful radiological technologists who utilize the technology from training and a successful quality control program of the CR system.

1.2 Research objectives

1.2.1 To determine patient radiation dose and the image quality before and after training the radiological technologists in simple radiographic projections using CR system.

1.2.2 To train radiological technologists about factors affecting patient dose and image quality.

CHAPTER II

REVIEW OF RELATED LITERATURES

2.1 Introduction to Computed Radiography

Computed Radiography (CR) is a marketing term for photostimulable phosphor (PSP) system. [5] Phosphors used in screen-film radiography such as Gd_2O_2S emit light promptly (virtually instantaneously) when struck by an x-ray beam. When x-rays are absorbed by photostimulable phosphors, some light is also promptly emitted, but much of the absorbed x-ray energy is trapped in the PSP screen and can be read out later. For this reason, PSP is also called strong phosphors or imaging plate. CR was introduced in the 1970s, increasing use in the late 1980s, and was in wide use at the turn of the century as many departments installed PACS, often in concert with the development of the electronic medical record.

2.1.1 PSP Image Acquisition

The PSP absorbed x-ray energy in crystal structure "traps," and is sometimes referred to as a "storage" phosphor. This trapped energy can be released if stimulated by additional light energy of the proper wavelength by the process of photostimulated luminescence (PSL)**.** Acquisition and display of the PSP image can be considered in five generalized steps, illustrated in Figure 2.1.

The unexposed PSP detector, commonly known as an imaging plate (IP), is placed in a cassette with a similar form factor and appearance of a screen-film cassette. X-ray geometry and imaging techniques are also similar to screen-film acquisition. During the exposure, x-rays are transmitted through the patient and absorbed by the IP. Energy deposited in the PSP material causes local electrons to be elevated from an equilibrium (ground state) energy level to a stable "trap" known as an "F-center." This is the unobservable "electronic" latent image, whereby the number of electrons trapped is proportional to the number of x-ray photons incident on the IP. The exposed IP in step 1 of Figure 2.1 must be read out to produce the x-ray image. In step 2, the cassette is placed in the reader where the IP is extracted and raster-scanned with a highly focused and intense laser light of low energy (~2 eV). Trapped electrons in the PSP matrix are stimulated by the laser energy, and a significant fraction return to the lowest energy level within the phosphor, with a simultaneous release of PSL of higher energy (~3 eV). The intensity of PSL, proportional to the number of released electrons, is optically filtered from the laser light and captured by a light guide assembly in close proximity to the IP. A photomultiplier tube (PMT) at the light guide output converts and amplifies the PSL into a corresponding output voltage.

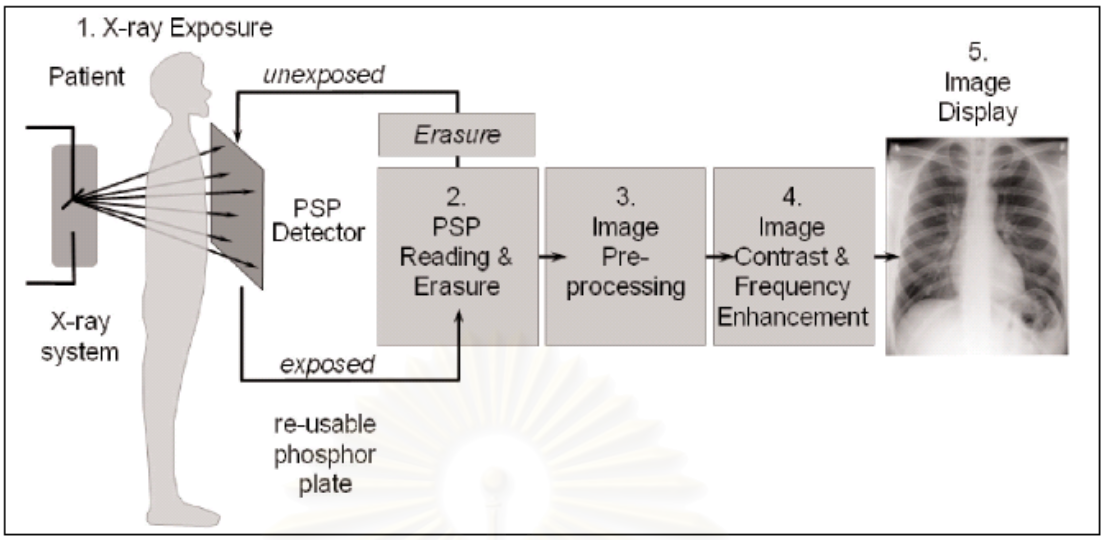

Figure 2.1 PSP Image acquisition and processing during x-ray exposure. There are five steps: (1) Image acquisition. (2) The resultant of latent image. (3) Image pre-processing. (4) Image post-processing. (5) The output of an image.

Subsequent digitization using an analog-to-digital converter (ADC) produces a corresponding digital number at a specific location in the digital image matrix determined by the synchronization of the laser beam and IP location. Residual latent image information is erased using an intense light (consisting of wavelengths that remove electrons in traps without stimulating further electron trapping), and the IP is reinserted into the cassette for reuse. Image preprocessing takes place in step 3, to correct for static light guide sensitivity variations and fixed noise patterns, so that the imaged object is faithfully reproduced and scaled to a normalized range as "raw" image data. Wide dynamic range response of the PSP detector requires image recognition, scaling, and contrast enhancement to optimize the image characteristics and signal-to-noise ratio (SNR) of the "processed" image data in step 4. Display of the digital image in step 5 uses look-up-table (LUT) transformations to properly render the digital image code values into corresponding grayscale brightness variations for soft-copy monitors and optical density (OD) values for hard-copy film. In terms of acquisition, the PSP system closely emulates the conventional screen-film detector paradigm. There are, however, several important differences relative to screen-film detectors to realize the full advantage of PSP imaging capabilities, including collimation and position of the object on the detector, variable (selectable) detector speed, sensitivity to x-ray scatter, importance of optimal image processing and image artifacts, among other issues.

2.1.2 PSP Detector Characteristics

PSP detectors are based on the principle of photostimulated luminescence [6-9]. When an x-ray photon deposits energy in a PSP material, it stores a significant fraction of the deposited energy in crystal structure defects, thus the synonym storage phosphors. This stored energy constitutes the latent image. Over time, the latent image fades spontaneously by the process of phosphorescence. If stimulated by light of the proper wavelength, the process of stimulated luminescence can release a portion of the

trapped energy immediately. The emitted light constitutes the signal for creating the digital image.

A typical PSP detector is layered on an opaque substrate, as illustrated in Figure 2.2a. A PSP detector with an optically transparent base allowing extraction of the PSL light from both sides when stimulated is now clinically available [10] as shown in Figure 2.2b, and a structured phosphor is under investigation, comprising CsBr (cesium bromide) [11,12] as artistically illustrated in Figure 2.2c. These latter two implementations show great promise in improving detection efficiency and image information transfer, resulting from improved detection efficiency and conversion efficiency. [4]

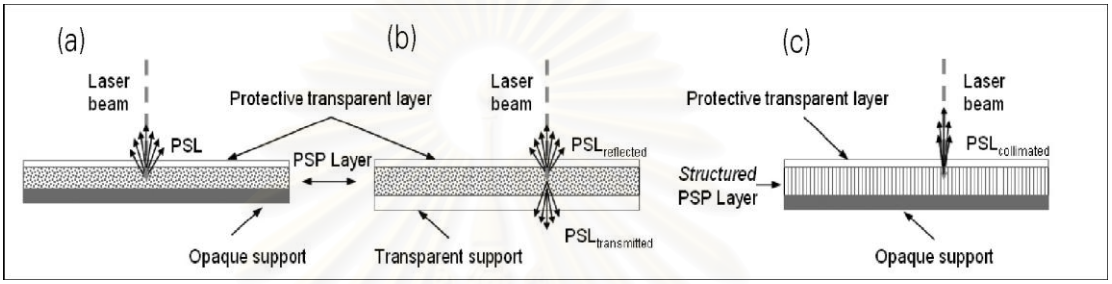

Figure 2.2 Cross-sectional views of the (a) generic, (b) dual-side readout, and (c) structured PSP detectors. Often, the opaque support will have a reflective layer to increase the PSL intensity.

Typical PSP is composed of about 85%BaFBr and 15%BaFI, activated with a small europium. This activation procedure, also called doping, creates defects in the BaFBr crystal that allow electron to be trapped more efficiently.

When the x-ray energy is absorbed by the BaFBr phosphor, the absorbed energy excites electrons associated with the europium atoms, causing divalent europium atoms (Eu^{+2}) to be oxidized and changed to the trivalent state (Eu^{+3}). The excited electrons become mobile, and some fraction of them interact with a so called F-center. The F-center traps these electrons in a higher energy metastable state, where they can remain for days to weeks, with some fading over time. The latent image that exists on the imaging plate after x-ray exposure, but before readout, exists as billions of electrons trapped in F-centers. The number of trapped electrons per unit area of the imaging plate is proportional to the intensity of x-rays incident at each location during the exposure.

When the red laser light scans the exposed imaging plate, the red light is absorbed at the F-center, where the energy of the red light is transformed to the electron. The photon energy of the red laser light is less than that of the blue-green emission, however, the electron gains enough energy to reach the conduction band, enabling it to become mobile again. Many of these electrons then become de-excited by releasing blue-green light as they become reabsorbed by the trivalent europium atoms, converting them back to the divalent state as in Figure 2.3. This is how the red laser light stimulates emission of the blue and green light photons from the imaging plate.

The first readout of the imaging plate does not release all of the trapped electrons that form the latent image; indeed, a plate can be read a second time and a third time when only slight degradation. To erase the latent image so that the imaging

plate can be reused for another exposure without ghosting, the plate is exposed to a very bright light source, which flushes almost all of the metastable electrons to their ground state, emptying most of the F-center.

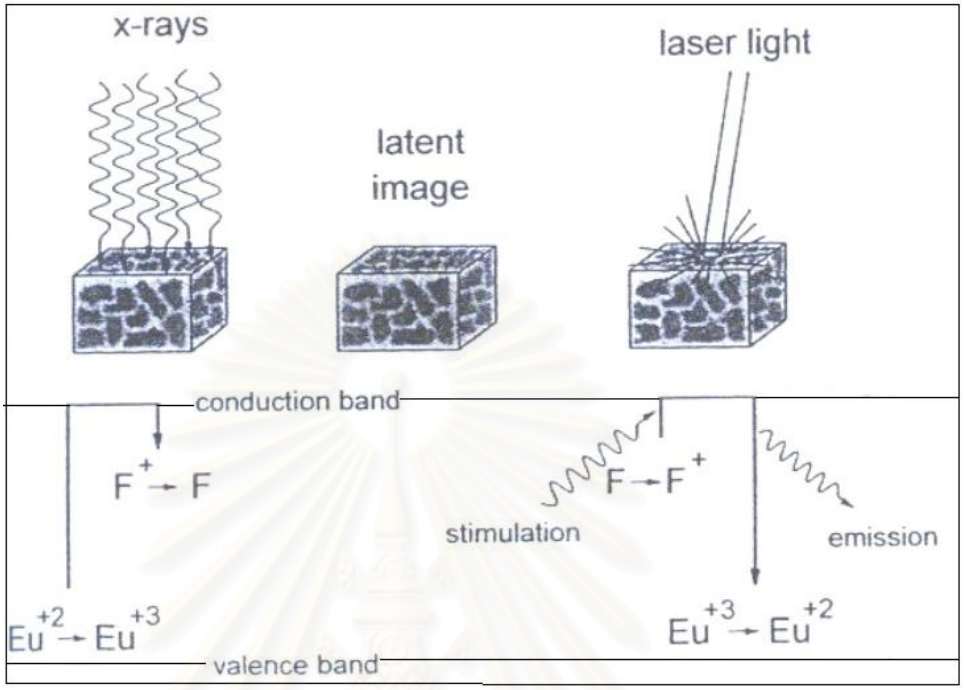

Figure 2.3 The sequence of events during the x-ray exposure and readout of a photostimulable phosphor.

2.1.3 The Readout Process

The PSP reader and basic components are illustrated in Figure 2.4.

2.1.3.1 Point-scan Laser Readout

Produced by either a HeNe or diode laser source, a focused laser beam is routed through several optical components prior to scanning the phosphor plate. (Note: Most current systems since about the year 2000 use a diode laser.) A beam splitter uses a portion of the laser output to monitor the incident laser intensity via a reference detector, and to compensate the output PSL signal intensity for incident power fluctuations. [14] The major portion of the laser energy reflects off a scanning device (rotating polygonal mirror or oscillating flat reflector), through an optical filter, shutter, and lens assembly. To maintain a constant focus and linear sweeping velocity across the PSP plate, the beam passes through an f-θ lens to a stationary mirror (typically a cylindrical and flat mirror combination). Typical laser "spot sizes" range from 50 μm to 200 μm and several sizes in between, depending on the manufacturer and reader as measured at the surface of the IP.

The speed of the laser beam across the phosphor plate is limited by the luminescent signal decay time constant (~0.7 to 0.8 μs for BaFBr: Eu^{2+}) following excitation [4] to maintain spatial resolution. Laser beam power determines the fraction of the electrons released from the F-centers, the fraction of phosphorescent lag, and the

amount of residual signal. Higher laser power can release more trapped electrons, but the trade-off is a loss of spatial resolution caused by increased laser penetration depth and wider spread of the stimulated light in the phosphor layer. Signal decay lag (afterglow) causes blur in the scan direction, and results in loss of high-frequency response near the Nyquist frequency. At the end of the scanned line, the laser beam is retraced to the start and repeated.

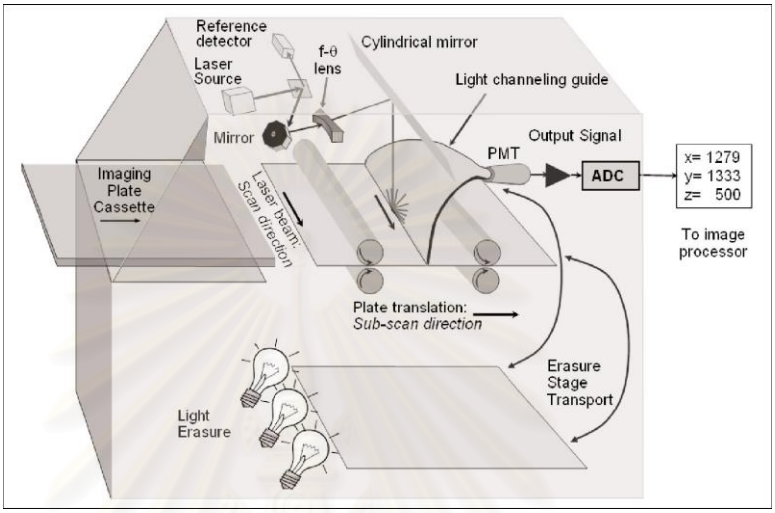

Figure 2.4 Major components of a PSP reader (point-scan, laser flying spot) include the stimulating laser source, a beam splitter, oscillating beam deflector, f-θ lens, cylindrical reflecting mirror, light collection guide, photomultiplier tube (PMT), and light erasure stage.

Translation of the IP through the optical stage occurs continuously at a speed to ensure an "effective" sample size is equal in both the laser scan and plate sub-scan dimensions. This imposes an upper limit to spatial resolution in both dimensions. [14] Scanning and plate translation continues in a raster fashion over the total phosphor area. Scan direction, laser scan direction, or fast-scan direction are equivalent terminology referring to the direction of the laser beam. Slow-scan, sub-scan, or translation direction refers to the phosphor plate travel direction. The typical scanning time is chiefly limited by the laser scan speed; for a 35x43 cm imaging plate, the time varies by manufacturer, reader type, and laser resolution. In general, a scan time range of ~30 to 60 seconds is specified by most manufacturers. Newer phosphor formulations with less signal decay lag (e.g., BaFI: Eu = ~0.6 μs) [4] allows a faster scan speed without loss of resolution in the laser scan direction. IP readout geometry for a point-scan PSP reader is shown in Figure 2.5.

2.1.3.2 Dual-side Laser Readout

In 2001, a "dual-side" IP was introduced to acquire both reflected and transmitted PSL from a stimulating point laser source, with two light guides positioned on either side of the detector (Figure 2.2.). In this configuration, a larger fraction of stimulated light is captured, and with optimized frequency weighting of the reflected and transmitted signals [10, 13] a higher SNR is achievable than with the conventional

single-sided readout, and good spatial resolution is maintained. As for comparison of detective quantum efficiency, enhancement of 40% to 50% has been reported [15, 16] which ultimately leads to improve dose efficiency and equivalent radiographic speed, or better SNR (as a selectable trade-off). Dual-side readout was initially produced for a prototype digital mammography detector, but is now being used for conventional PSP applications on readers with two light guides, in conjunction with the transparent base IP

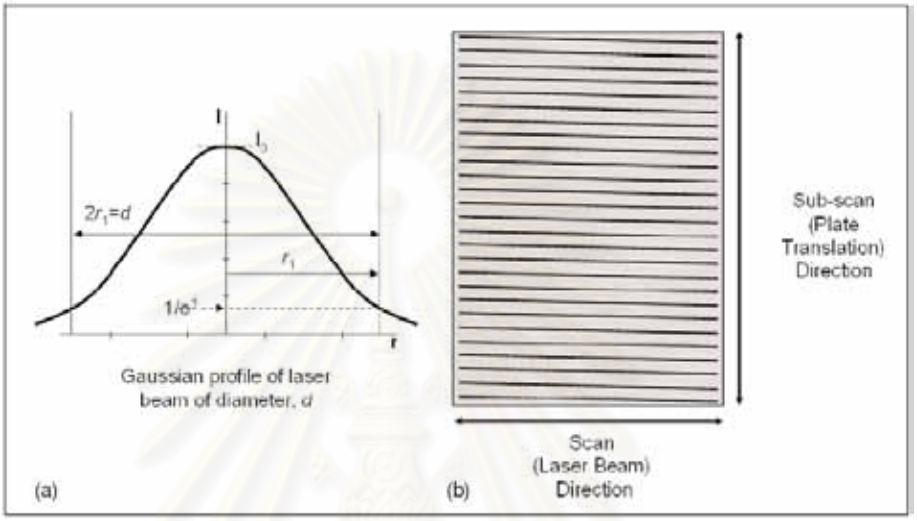

Figure 2.5 (a) Beam profile of laser of diameter *d*. (b) Diagram of the raster-scan of the phosphor detector indicates the fast-scan (laser scan) direction and the sub-scan (plate translation) direction. Note the slightly skewed angle of the readout lines relative to the edge of the phosphor plate, due to the simultaneous laser beam scanning and plate translation.

2.1.3.3 Line-scan Laser Readout

PSP systems based upon a laser line source coupled to an array of CCD photosensors were first clinically introduced in late 2003. These systems can read the latent image on a PSP plate in 5 to 10 seconds for a large FOV (35x43 cm) detector [16,17] The schematic diagram in Figure 2.6 depicts the general configuration of a line-scan PSP system. Line excitation and readout of the IP reduces readout time by a large factor compared to a point scan system, without being limited by signal decay (phosphorescence) lag. A compact diode laser line source and micro-lenses to focus the PSL light photons onto the CCD photodiode array allow a small footprint and overall detector size. Line-scan PSP systems are competitive with DR devices in terms of processing speed, form-factor, and ease of use, with image performance similar to point-scan PSP systems [4, 12]

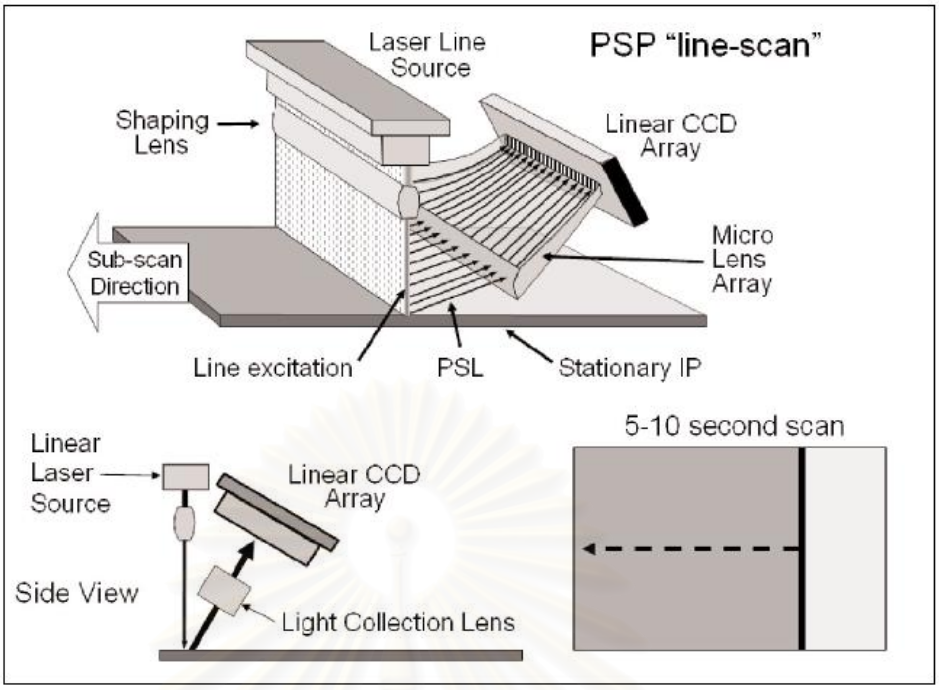

Figure 2.6 A "line-scan" PSP system, top, showing the general configuration, and bottom illustrating the side view of the components including the laser and light collection micro-lens array, and the geometry of acquisition.

2.1.3.4 Digitization

Digitization is a two-step process of converting a continuous analog signal into a series of discrete digital values. The signal must be sampled and quantized. Sampling determines the location and size of the PSL signal from a specific area of the PSP detector, and quantizing determines the average value of the signal amplitude within the sample area. The output of the PMT is measured at a specific temporal frequency coordinated with the laser scan rate, and quantized to a discrete integer value dependent on the amplitude of the signal and the total number of possible digital values. The ADC converts the PMT signals at a rate corresponding to the number of pixels in the scan direction divided by the time per line. A pixel clock is synchronized to the absolute scan beam position and the corresponding position in the digital matrix. The translation speed of the phosphor plate in the sub-scan direction coordinates with the fast-scan pixel dimension so that the width of the line is equal to the length of the pixel (i.e., the pixels are "square"). The pixel pitch (distance between samples) is typically between 100 and 200 mm, depending on the dimensions of the IP, but may be as small as 50 μm. for dedicated mammography systems. The sampling aperture is the area over which the signal information is averaged. This is determined by the laser beam distribution, and ideally is equal to the full-width-half-maximum (FWHM). Since the distribution has a Gaussian shape, the generated PSL signal extends beyond the pixel aperture, and the measured spatial resolution is usually less than what the pixel pitch and pixel aperture settings infer.

Although the analog output from the PMT has an infinite range of possible values between a minimum and maximum voltage, the ADC breaks the signal into a series of discrete integer values (analog-to-digital units or "code values") for encoding signal amplitude. The number of bits used to approximate the analog signal, or "pixel

depth" determines the number of integer values. PSP systems typically have 10 to 16 bit ADCs, so there are 2^{10} =1024 to 2^{16} = 65,536 possible code values for a given analog signal amplitude. One manufacturer uses a very large bit depth (16 bits or greater) to implement a digital logarithmic transformation to a final 12-bit/pixel image. Other system manufacturers use an analog logarithmic amplifier or a square- root amplifier on the predigitized signal. Analog amplification avoids quantization errors in the signal estimate when the number of ADC bits (quantization levels) is limited. [18]

2.1.4 Digital versus Analog Process

Although image receptors are referred to as "digital" the initial stage of these devices produces an analog signal. In CR, a photomultiplier tube detects the visible light emitted from the photostimulable phosphor plate and produces a current that is subsequently digitized.

2.1.5 Detector Characteristic Response

A linear, wide latitude response to variations in incident exposure is characteristic of the phosphor plate, while film is optimally sensitive to a restricted range of exposures. Figure 2.7 illustrates the characteristic curve response of a typical PSP detector to a 400-speed screen-film system. For screen-film detectors, which serve as both the acquisition and the display medium, it is necessary to tune the detector (film) contrast and radiographic speed to a narrow exposure range to achieve images with optimal contrast and minimal noise characteristics. PSP (and DR) detectors are not constrained by the same requirements because the acquisition and display events occur separately, and compensation for under and overexposures is possible by appropriate amplification of the digital data. However, identification of useful signal range must be accomplished prior to the auto-ranging and contrast enhancement of the output image. In addition, since under or overexposed images can be "masked" by the system, a method to track exposures on an image-by-image basis is necessary to recognize those situations that exceed the desired or target exposure range so that action can be taken to resolve any problems. Of particular note is the broad range of over-exposure as shown in Figure 2.7, which can lead to "dose creep" (a subtle or gradual and potentially unnoticed increase in exposure when using digital detectors) [19] and excessive radiation dose to the patient. Exposure ranges marked "useless" represent average incident exposures that produce a significant fraction of signals over the image either so small as to be dominated by quantum noise, or so extreme as to be saturated. In either case, amplification adjustments cannot be made to extract any pertinent image information.

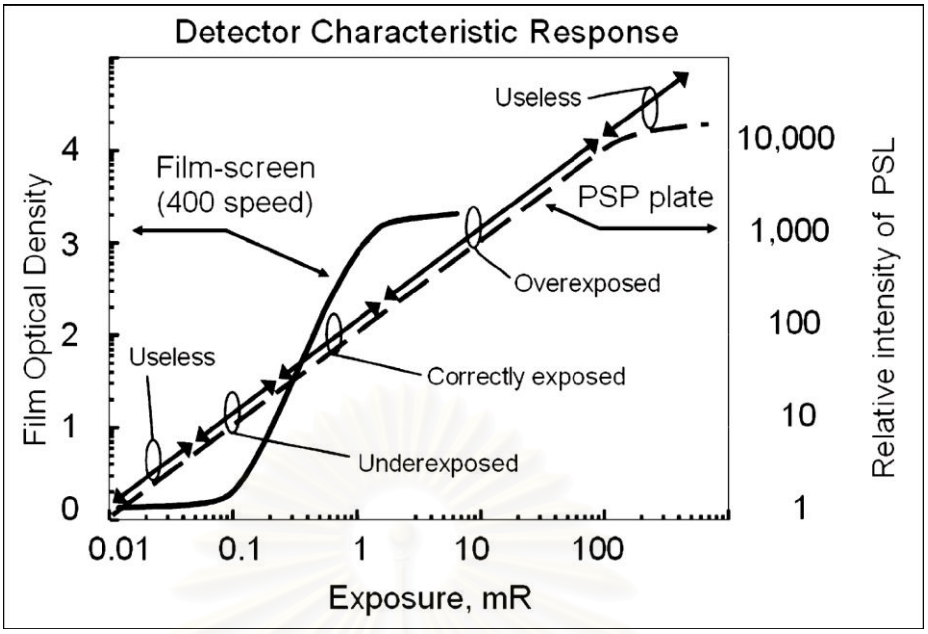

Figure 2.7 The characteristic response of a 400-speed rare-earth screen-film (solid S-shaped curve) and the PSP detector (dashed curve) are compared. Double arrows roughly indicate the exposure ranges characterized as underexposed, correct, or overexposed. "Useless" areas depict system responses that do not contain information useful for diagnosis either due to excessive quantum noise or saturation of the PSL mapped to digital number.

2.1.6 Contrast versus Spatial Resolution in Digital Imaging

When an analog image is partitioned into a digital matrix of numbers, compromises are made. As an example, screen-film mammography produces images with measurable spatial resolution beyond 20 cycles/mm. To obtain this resolution with a digital image, 25 μm pixels would be required, resulting in a 7,200 x 9,600 pixel image. Images of this size cannot be displayed (at full resolution) on any monitor and storing huge images is expensive as well. Consequently, digital radiographic images are invariably lower in spatial resolution than their analog screen-film counterparts Figure 2.8, both for mammography and for general diagnostic radiography.

Images in digital format have advantages as well. The ability to transmit images electronically to produce identical copies that can be in multiple locations at the same time and to archive images using computers instead of long rows of shelves represents practical advantages. Digital technology is clearly where diagnostic radiology is headed. The abilities to read just the contrast of an image after detection is an under appreciated feature of digital images that leads to improved interpretation and better diagnosis. Digital detector systems may not produce spatial resolution equal to that of film but the contrast resolution (at equivalent radiation dose level) is superior for most digital radiographic system compare with screen-film systems. The combination of improved resolution (better DQE) and improved contrast (window/level) can lead to an overall improvement in diagnostic performance for a significant fraction of clinical examinations. Under a wide array of circumstances, the improvement in contrast resolution that digital images provide outweighs the slight loss in spatial resolution.

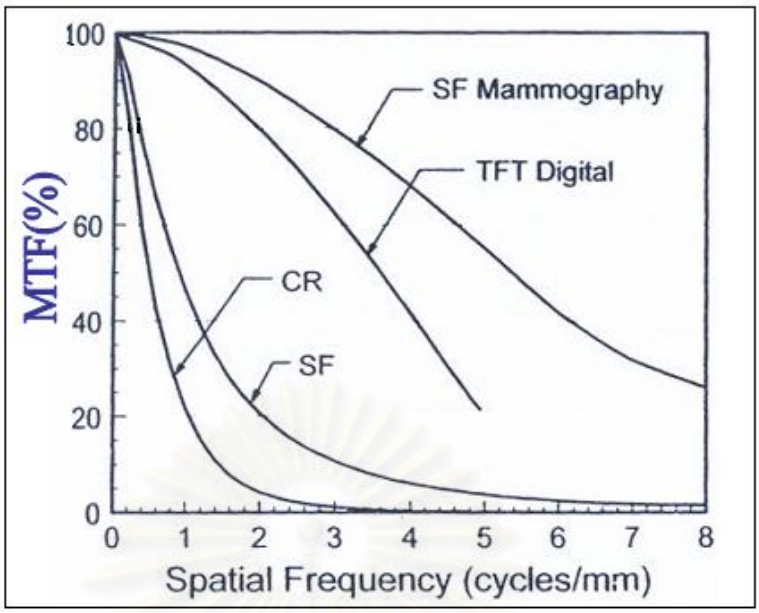

Figure 2.8 The modulation transfer function (MTFs) are shown for several modalities. SF, screen-film; CR, computed radiography; SF Mammography, screen-film mammography; TFT Digital, direct detection 100-μm pixel flat panel detector system.

2.2 Implementation

The choice of a digital detector system requires a careful assessment of the needs of the facility. CR is often the first digital radiographic system that is installed in a hospital because it can be used for providing portable examination where the cost of retakes in both time and money is high. CR plates themselves are relatively inexpensive, several dozen plates may be used in different radiographic rooms simultaneously. The number of room that one CR reader can serve depends on the type of rooms, workload and proximity. Typically one CR reader can handle the workload of three radiographic rooms.

2.3 Patient Dose Consideration

When film-screen image receptors are used, an inadvertent overexposure of the patient will result in a dark film, which provides immediate feedback to the technologist regarding the technique fraction (and relative dose) used. However, when digital image receptors are used, overexposure of the patient can produce excellent image because the electronic system compensate for (an essentially mask) fluctuations in exposure. Consequently, high-exposure condition may go unnoticed unless appropriate measures for periodic monitoring are taken. For this reason, a quality control program should be in place to ensure proper exposure levels. Most digital detector systems provide an estimate of the incident exposure that can assist in the evaluation of exposure trends. The exposure necessary to produce good images are directly related to the detective quantum efficiency (DQE) of the detector. Detectors with high DQEs make more efficient use of the x-rays and therefore require less exposure for adequate signal-to-noise ratios. X-ray exposure levels should be tailored to the needs of the specific clinical examination, in consideration of the digital detector and its DQE.

2.4 Guidance or Reference Levels

International Commission for Radiological Protection ICRP [20] proposed the use of diagnostic reference levels for radiation doses to patients. These levels, which are the form of investigation level, apply to an easily measurable quantity, often ESD, which in normal practice should not be exceeded. They are only intended to be a guide to those doses which if exceeded, should prompt a review of practice in order to optimize patient dose. If the dose also falls substantially below reference levels, it is possible that the intended diagnostic information is not being collected.

2.5 Application Training for Technologists, Radiologists, Physicists, Clinical Engineers

When PSP radiography is introduced into a conventional radiography operation, specific reference to applications training should be indicated, even when the vendor has a standard level of applications training with the sale of the equipment, initial technologist training is essential.[21] The technologist must understand the importance of selecting the proper examination, must learn to recognize the related artifacts, and must have some idea how to correct inferior images.[22] Appropriate actions with PSP systems are often anti-intuitive to technologists well versed in screen-film radiography. A minimum of 1-week, on-site training is recommended for technologists (include work shift hours as necessary). A super-tech is specified for advanced training at the manufacturer's facility. Radiologists should interact with the application specialist during the initial startup of the system to implement specific image processing algorithms appropriate for each examination. Physicists should be aware of processing algorithm tuning functions and be instructed on processing variables, effects on image appearance, and adjustment procedures. Hospital engineering staff should be trained for simple preventive maintenance tasks and error recovery issues. In addition, these individuals should also have the option of attending a training program designed for preventive maintenance and in-depth system repairs, particularly in the absence of a warranty agreement.

2.6 Review of related literatures

While the digital technology is converted at department of radiology, several careful attentions on radiation protection of digital radiology must be paid; medical exposure of patients can increase significantly without concurrent benefit. [23] The transition from conventional screen-film to computed or digital radiography can entail an increase in patient radiation doses. One of the main causes is the wide dynamic range of the digital imaging systems, which allows overexposure with no adverse effect on image quality [24]

Digital radiographic images can be obtained at a low dose owing to the high detective quantum efficiency (DQE). These fundamental differences in comparison to conventional film/screens necessitate the development of new strategies for dose and quality optimizations.[25] Although in the study of Smith CK, et al.[26], radiographic exposure of chest CR using low exposure has shown that there was a significant decrease in low contrast object such as lung nodule detection. This result was associated with a decreasing in signal to noise ratio. In addition, the lack of specific

training in the new digital techniques for the radiological technologists and the lack of well-established methods to audit patient dose in digital system can worsen the problem of patient radiation exposure.

The International Commission on Radiological Protection (ICRP) became aware of the risk and launched several specific recommendations to manage patient dose in digital and computed radiology. [27] It is expected that the ICRP report helps to profit from the benefits of this important technological advance in medical imaging with the best management of radiation doses to the patients. Training actions before the digital techniques are introduced in the radiology departments the manufacturers should offer enough technical and dosimetric information to help optimization of the imaging. These recommendations also include appropriate training, particular in aspects of patient dose management, revision of the diagnostic reference levels (DRLs) and frequent patient dose audits. [28]

These are also the common goal as the IAEA recommended that the awareness of the dose implications of new imaging technology should be increased. The advice to member on how to manage the change, provided reduce dose and maintain a high quality imaging service should be considered.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Research design

This study is an experimental prospective design to determine patient radiation dose and image quality in routine x-ray examination using computed radiography (CR) system. The result will be compared before and after training program of the radiological technologists on the principle of CR system, image quality criteria and dose reference level (DRLs).

3.2 Research design model

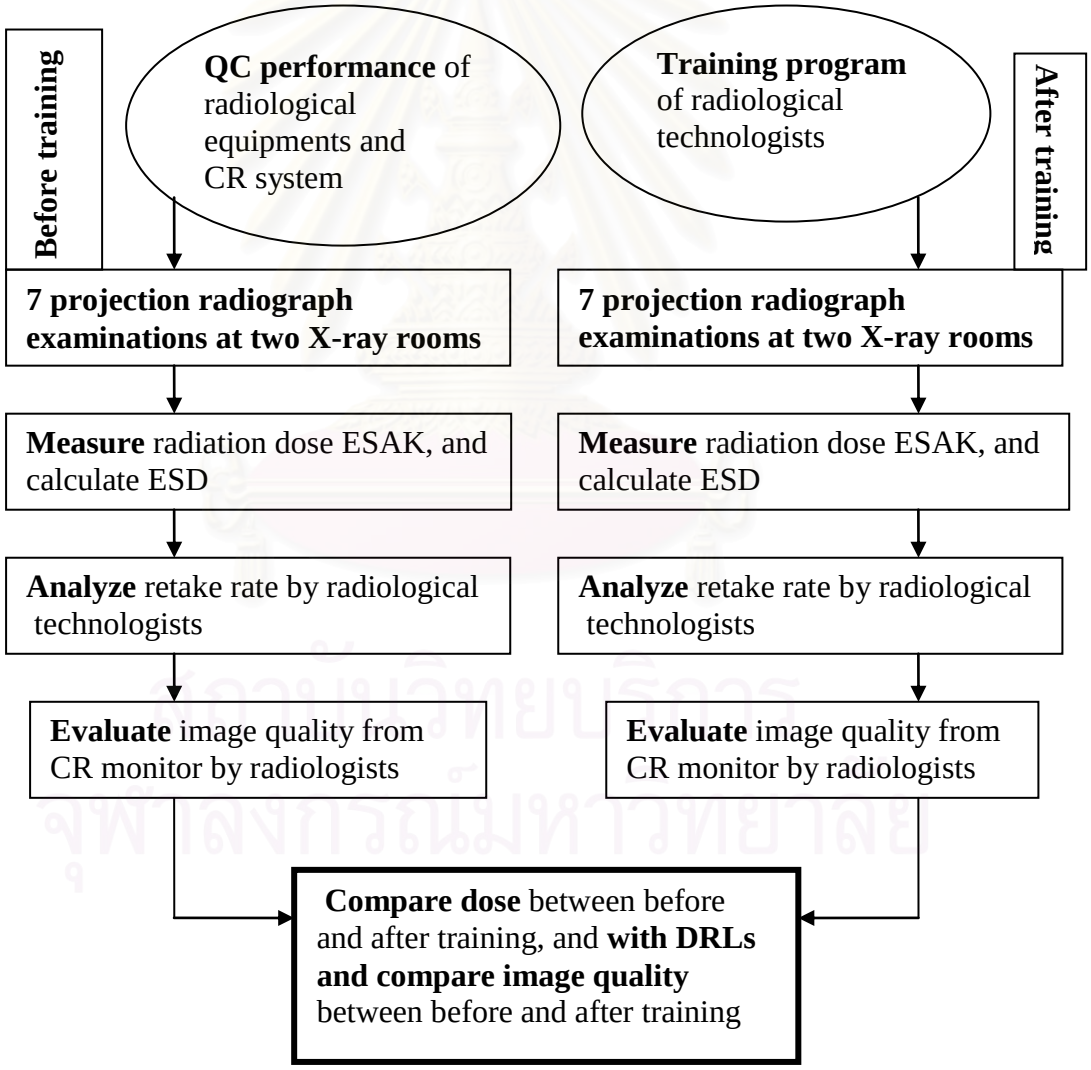

Figure 3.1 Research design model

3.3 Conceptual framework

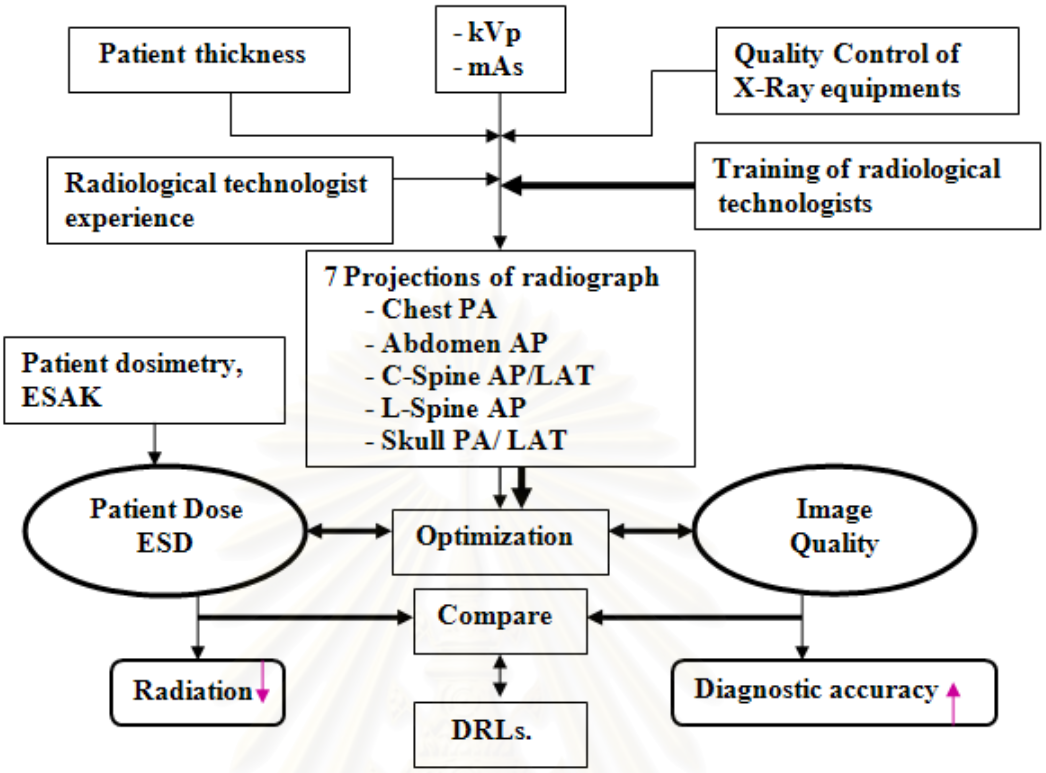

Figure 3.2 Conceptual framework

3.4 Research questions

Primary question: What are the patient radiation dose and the image quality before and after training the radiological technologists in simple radiographic projections using CR system?

Secondary question: Is the patient radiation dose after training the radiological technologists less than dose reference level?

3.5 Hypothesis

H_0: The patient radiation dose and the image quality do not improve after training radiological technologists.

H_a: The patient radiation dose and the image quality improve after training radiological technologists

3.6 Key words

- Computed Radiography (CR)

An x-ray imaging technique which uses a photostimulable phosphor as the image recording medium.

- **Kerma**
  The kinetic energy released per unit mass in a medium from x or gamma rays.
- **Entrance Skin Dose (ESD)**
  Absorbed dose to the skin entrance point including the backscatter factor.
- **Diagnostic Reference Levels (DRLs)**
  A reference of absorbed dose value quantifying patient dose of standard radiographic exposure (for standard patients).
- **Image Quality**
  Quality of the radiographic image as follows the diagnostic requirement, European criteria (Appendix B).

3.7 The sample

3.7.1 Target population All patients who were requested by medical doctors for general radiography at Rajavithee Hospital.

3.7.2 Sample population All patients who were requested by medical doctors for general radiography at Rajavithee Hospital.

3.7.3 Eligible criteria;

3.7.3.1 Inclusion criteria

a.) The patients under the following 7 projections examination: Chest PA, Abdomen AP, Cervical spine AP, Lumbar spine AP and LAT, Skull PA and LAT

b.) Conscious patients

c.) Patient age is between 15-75 years with body weight between 35 - 110 kilograms.

3.7.3.2. Exclusion criteria

a.) Emergency or acute disease patients who can not co-operate.

b.) Pregnant patients.

3.7.3.3. Sample size determination

Sample size (n) is calculated and evaluated using the equation (3.1).The data compares between two dependent groups, then

$$\mathbf{n = \frac{(Z_{\alpha/2}+Z_{\beta})^2\sigma^2}{d^2}} \quad \text{.....[3.1]}$$

Given confidence interval (CI) 95%, α is 0.05, and $\mathbf{Z_{\alpha/2}}$ is 1.96 (two tails)

At power 90 %, β is 0.10 and $\mathbf{Z_{\beta}}$ is 1.28

σ^2 = **Variance of difference**: $\sigma_1^2 + \sigma_2^2 - 2\,\mathbf{r}\,\sigma_1\,\sigma_2$

σ_1^2 = Variance of before group of training

σ_2^2 = Variance of after group of training

r = Correlation coefficient of before and after group of training; 0.5

d = Difference**:** mean of difference in before and after group of training

To review related literature [30] and substitute data into equation (3.1), then sample size,n for chest PA projection is

Chest- PA $= \frac{(1.96+1.28)^2[(0.04^2+0.09^2) - 2(0.5)(0.04)(0.09)]}{(0.03)^2} = 71.15 \approx 72$

To calculate all the rest of the projections in the same way and define sample size of before the training in n_b, and after the training in n_a, so n_b equals n_a **;**

n_b (Chest-PA)	= n_a (Chest-PA)	= **72**
n_b (Abd-AP)	= n_a (Abd-AP)	= 58
n_b (Csp-AP)	= n_a (Csp-AP)	= 18
n_b (Lsp-AP)	= n_a (Lsp-AP)	= 31
n_b (Lsp-LAt)	= n_a (Lsp-LAT)	= 39
n_b (Skl-PA)	= n_a (Skl-PA)	= 6
n_b (Skl-LAT)	= n_a (Skl-LAT)	= 5

3.8 Materials

3.8.1. Two X-ray rooms at Department of Radiology, Rajavithi Hospital, Ministry of Public Health.

3.8.1.1 Emergency Medical Service room **(EMS**) consists of

i.) X-ray system,
- Bennett B-OTC, USA (Figure 3.3a, 3.3b), installation June 01,2000

ii.) CR system,
- CR Reader, Fuji FCR Capsula, Japan (Figure 3.3c), Installation Nov 30, 2006

iii.) Printer, Fuji Drypix 7000, Japan (Figure3.3d), installation Nov 30, 2006


3.3a


3.3b.

Figure 3.3a,3.3b X-ray system, Bennett B-OTC,USA

Figure 3.3c CR Reader, Fuji FCR Capsula **Figure 3.3d** Printer, Fuji Drypix 7000

3.8.1.2. X-ray Room number 4 consists of

i.) X-ray system,

- Trex linear MC-150, USA (Figure 3.4a, 3.4b), installation Jun 29, 2000

ii.) CR system,

- CR Reader, Fuji FCR Profect, Japan (Figure3. 4c), installation Nov 30, 2006

iii.) Printer, Fuji Drypix 7000, Japan (Figure 3.4d), installation Nov 30, 2006

Figure 3.4a, 3.4b X-ray system, Trex linear MC-150, USA

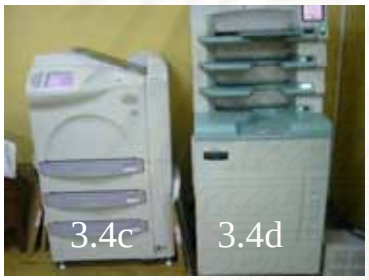

Figure 3.4c. CR Reader, Fuji FCR Profect,
3.4d. Printer, Fuji Drypix 7000.

Figure 3.5a. Imaging plate
3.5b. Film DI_HL

3.8.2 Accessories

3.8.2.1. Imaging plates, Fuji (Figure 3.5a), size 35x43 cm^2, 26x36 cm^2 , 20x25 cm^2

3.8.2.2. Film DI-HL, Fuji (Figure 3.5b), size 35x43 cm^2, 26x36 $cm^{2,}$ 20x25 cm^2

3.8.2.3. CR system workstation, Fuji. (Figure 3.6a, 3.6b)

Figure 3.6a. CR system, Fuji.

Figure 3.6b. Diagnostic monitor

3.8.2.4. Ruler for patient thickness measurement (Figure 3.7)

3.8.2.5. Solid state dosemeter UNFORS model Xi (Figure 3.8)

3.8.2.6. QC equipments (Figure 3.9)

3.8.2.7. 458 Patients : 144 Chest PA, 116 Abdomen AP, 36 Cervical spine AP, 62 Lumbar spine AP, 78 Lumbar spine LAT, 12 Skull PA and 10 Skull LAT

3.8.2.8. Case record forms (Appendix E)

Figure 3.7. Ruler

Figure 3.8. Solid state dosemeter UNFORS model Xi

Figure 3.9. QC equipments

3.9 Methods

The study consists of two phases. The first phase involves the determination of patient dose and image quality at routine technique of CR system. The second phase involves the patient dose and image quality after training of radiological technologists. The details are as following:

3.9.1 <u>Phase I</u> (Control data): The study of retake rate, image quality and patient dose.

3.9.1.1. Collect retake rate at the radiological technologist's level, image quality grading in A, B and C on diagnostic monitor of CR system by radiologists (A – Clearly accepted without any remark or reservation, B – accepted with some remarks or reservation, C – Rejected.)

i.) Collect the retake data within 1 month by the radiological technologist

ii.) Record number of images; retake rate as in B and C.

iii.) Analyze the causes of retake such as

- Patient positioning
- Motion
- Artifacts
- Field size misplacement
- Others

3.9.1.2. Determine the retake rate and image quality.
3.9.1.3. Perform quality control of X-ray equipment to obtain the radiation output (mGy/mAs) at different kVp.
3.9.1.4. Record patient thickness in centimeter, focal skin distance (FSD) in centimeter and exposure parameters of kVp, mAs of 7 projections as,

i.) Chest PA
ii.) Abdomen AP
iii.) C-Spine AP
iv.) L-Spine AP, LAT
v.) Skull PA, LAT

3.9.1.5. Calculate the patient entrance skin air kerma, ESAK (mGy)
3.9.1.6. Calculate the patient dose, ESD (mGy), for each projection
3.9.1.7. Educate the radiological technologists by setting up the training program.

The training program is the intervention of the research design. The contents of the training are basic principles of CR, DR and the applications, method of image quality determination, reject analysis procedures and image quality technique in radiography. Standard practices will be demonstrated and to compare with the alternative techniques to minimize the radiation dose, and the diagnostic reference levels (DRLs). The dose measurement method will be expressed as entrance surface air kerma (ESAK) where the entrance skin dose (ESD) is assessed. ESD can be calculated by the following equations.

$$\textbf{ESAK} = \textbf{AK(100cm.)x (100/FSD,cm.)}^2 \quad \textbf{……..[3.2]}$$

$$\textbf{ESD} = \textbf{ESAK(mGy)x BSF} \quad \textbf{…….....…..[3.3]}$$

ESAK = Entrance Skin Air Kerma
FSD = Focal Skin Distance
BSF = Back Scatter Factor
ESD = Entrance Skin Dose

At the end of this training, the participants will be able to optimize the patient dose for simple radiography. There will be 18 radiological technologists and 2 radiologists participation the program. The detail of the study plan is as following

3.9.2 Study Plan

Topic: Optimization of radiation dose and the image quality on Computed Radiographic image in routine simple projections.

Instructor: 1. *Associate Professor Anchali Krisanachinda, Ph.D.
2. **Dr. Siripun Kalayanarooj, M.D.
3. ***Ms.Petcharleeya Suwanpradit, M.Sc
4. ****Ms.Sunee Lumlertdacha, B.Sc

*Department of Radiology, Faculty of Medicine, Chulalongkorn University.
**Department of Radiology, Diagnosis section, Rajavithi Hospital.
***Department of Radiology, King Chulalongkorn Memorial Hospital, Thai Red Cross Society.

****Medical imaging, Department of Radiology, Faculty of Medicine, Chulalongkorn University.

Learning objectives: At the end of the program, the participants should be able to:

1. Identify the causes of reject images
2. Reduce the number of reject images
3. Use the proper CR technique
4. Determine the patient dose from CR routine studies
5. Determine the guidance level of the patient dose in routine studies
6. Optimize the patient dose and image quality

Learning contents	Hrs.
1. Principles of CR and DR, applications	2
2. Performance of good radiographic technique	0.5
3. The causes of image retake	1
4. Quality criteria for diagnostic radiographic image	0.5
5. Criteria for radiation dose to the patient	1
6. Guideline on radiation dose to the patient	1

Method : Lecture and discussion 6 hrs.

Media: Power point presentation for lecture

Evaluation: 1. Observe the number of rejection image after training
2. Patient dose from each projection
3. Result from assessment by MCQs before and after the training

3.9.3. <u>Phase II</u> Patient radiation dose and image quality determination after education of radiological technologists.

3.9.3.1. Identify the same X-Ray rooms and the detail of the x-ray equipment, the same radiological technologists and same radiologists as phase I

3.9.3.2. Following step 3.9.1.1 to step 3.9.1.6 (except step 3.9.1.3) as phase I

3.9.3.3. Compare the patient dose between phase I and II, diagnostic reference levels DRLs, and image quality.

To provide image quality justification, two radiologists with similar clinical experience will evaluate the image quality base on the criteria [29]. All images will be assessed by radiologists independently and randomly in both before and after the training program in order to prevent learning bias. Each session will be presented not more than 30 images. No time constraints are imposed. All images will be viewed on a diagnostic monitor passing quality control on CR system.

3.10 Statistical analysis

This study involves the comparison between two dependent groups. Paired T-test is chosen for data analyzing and routine statistical data were analyzed by using SPSS version 16 for window to test the hypothesis.

3.11 Ethical considerations

This study is performed in patients by collecting general information such as the weight, height and thickness of body part examined as projects selection. (Appendix G). The ethical has been approved by Ethics Committee of Faculty of Medicine, Chulalongkorn University.

3.12 Expected benefits

3.12.1. The patient entrance skin dose (ESD) and image quality undergoing simple examinations radiography for CR system.

3.12.2. The reduction of the patient radiation dose while maintaining good image quality.

3.12.3. Improve quality of service by saving time, and resources.

CHAPTER IV

RESULTS

4.1 The quality control of X-ray and CR systems

The results on quality control of two X-ray and CR systems were within acceptable range of AAPM protocol (Appendix A)

4.2 Patient doses, image quality grading and retake analysis before training program

4.2.1 Patient doses

The total 458 patients were divided into before and after training program. The patient dose has been calculated, backscatter factors were applied to the ESAK data to obtain ESD. Once the appropriate backscatter factors from Petoussi-Hens[31] was chosen for any kVp (Appendix D). Before training program, data were separated into two rooms, No.4 and EMS in totally 229 patients

Data from Room No.4 was patient information, exposure parameters, mean FSD, mean ESAK, and mean ESD for thickness range of each x-ray projection were shown in Table 4.1-4.7

For chest PA, thickness 14-18 cm. number of male and female patients were 2 and 3, mean weight was 58 kg., mean kVp was 120 , mean mAs was 3.4 , mean FSD was 161.6 cm, mean ESAK was 0.11 mGy, and mean ESD was 0.17 mGy. At thickness 19-23 cm number of male and female patients were 11 and 13, mean weight was 61 kg., mean kVp was 120 , mean mAs was 4.4 , mean FSD was 158.3 cm, mean ESAK was 0.15 mGy, and mean ESD was 0.23 mGy. At thickness 24-28 cm number of male and female patients were 4 and 2, mean weight was 85 kg., mean kVp was 120 , mean mAs was 5.6, mean FSD was 153.9 cm, mean ESAK was 0.21 mGy, and mean ESD was 0.31 mGy as shown in Table 4.1

Table 4.1 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in Chest PA projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-18	2/3	58	120	3.4	161.1	0.11	0.17
19-23	11/13	61	120	4.4	158.3	0.15	0.23
24-28	4/2	85	120	5.6	153.9	0.21	0.31
	17/18=35		*120				

For abdomen AP, thickness 15-20 cm. number of male and female patients were 7 and 2, mean weight was 57 kg., mean kVp was 75, mean mAs was 29, mean FSD was 75.6 cm, mean ESAK was 1.81 mGy, and mean ESD was 2.52 mGy. At thickness 21-26 cm number of male and female patients were 6 and 8, mean weight was 64 kg., mean kVp was 79 , mean mAs was 33, mean FSD was 70.1 cm, mean ESAK was 3.86 mGy, and mean ESD was 3.86 mGy. At thickness 27-32 cm, there was no data, as shown in Table 4.2

Table 4.2 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in abdomen AP projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
15-20	7/2	57	75	29	75.6	1.81	2.52
21-26	6/8	64	79	33	70.1	2.74	3.86
27-32	-	-	-	-	-	-	-
	13/10=23		*70-85				

For cervical spine AP, thickness 8-9 cm. number of male and female patients were 0 and 1, mean weight was 59 kg., mean kVp was 60, mean mAs was 6, mean FSD was 83.3 cm, mean ESAK was 0.18 mGy, and mean ESD was 0.24 mGy. At thickness 10-11 cm number of male and female patients were 0 and 7, mean weight was 62 kg., mean kVp was 64 , mean mAs was 6.4 , mean ESAK was 0.23 mGy., mean ESD was 0.31 mGy and mean FSD was 82.6 cm. At thickness 12-13 cm number of male and female patients were 1 and 0, mean weight was 67 kg., mean kVp was 70 , mean mAs was 7 , mean FSD was 80.8 cm, mean ESAK was 0.33 mGy, and mean ESD was 0.45 mGy as shown in Table 4.3

Table 4.3 Patients information, exposure parameters mean FSD, mean ESAK, and mean ESD in cervical spine AP projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
8-9	0/1	59	60	6	83.3	0.18	0.24
10-11	0/7	62	64	6.4	82.6	0.23	0.31
12-13	1/0	67	70	7	80.8	0.33	0.45
	1/8=9		*60-70				

For lumbar spine AP, thickness 15-20 cm. number of male and female patients were 4 and 5, mean weight was 57 kg., mean kVp was 78 , mean mAs was 28 , mean FSD was 75.8 cm, mean ESAK was 1.87 mGy, and mean ESD was 2.62 mGy. At thickness 21-26 cm number of male and female patients were 1 and 5, mean weight was 66 kg., mean kVp was 80 , mean mAs was 31 , mean FSD was 70.1 cm, mean ESAK was 2.57 mGy, and mean ESD was 3.62 mGy. At thickness 27-32 cm, there was no data, as shown in Table 4.4

Table 4.4 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in lumbar spine AP projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
15-20	4/5	57	78	28	75.8	1.87	2.62
21-26	1/5	66	80	31	70.1	2.57	3.62
27-32	-	-	-	-	-	-	-
	5/10=15		*75-85				

For lumbar spine LAT, thickness 18-21 cm. there was no data. At thickness 22-25 cm number of male and female patients were 5 and 8, mean weight was 57 kg., mean kVp was 88 , mean mAs was 53 , mean FSD was 69 cm, mean ESAK was 5.94 mGy, and mean ESD was 8.44 mGy. At thickness 26-29 cm number of male and female patients were 2 and 5, mean weight was 68 kg., mean kVp was 90 , mean mAs was 58, mean FSD was 65.6 cm, mean ESAK was 6.86 mGy, and mean ESD was 9.80 mGy as shown in Table 4.5

Table 4.5 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in lumbar spine LAT projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
18-21	-	-	-	-	-	-	-
22-25	5/8	57	88	53	69.0	5.94	8.44
26-29	2/5	68	90	58	65.6	6.86	9.80
	7/13=20		*85-90				

For skull PA, thickness 14-15 cm number of male and female patients were 1 and 0, mean weight was 46 kg., mean kVp was 70 , mean mAs was 26, mean FSD was 77.8 cm, mean ESAK was 1.36 mGy, and mean ESD was 1.85 mGy. At thickness 16-17 cm number of male and female patients were 0 and 1, mean weight was 57 kg., mean kVp was 70 , mean mAs was 26 , mean FSD was 76.8 cm, mean ESAK was 1.38 mGy, and mean ESD was 1.85 mGy. At thickness 18-19 cm number of male and female patients were 1 and 0, mean weight was 69 kg., mean kVp was 70 , mean mAs was 26 , mean FSD was 74.3 cm, mean ESAK was 1.59 mGy, and mean ESD was 2.13 mGy as shown in Table 4.6

Table 4.6 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in skull PA projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-15	1/0	46	70	26	77.8	1.36	1.85
16-17	0/1	57	70	26	76.8	1.38	1.85
18-19	1/0	69	70	26	74.3	1.59	2.13
	2/1=3		*70				

For skull LAT, thickness 14-15 cm number of male and female patients were 1 and 1 mean weight was 51 kg., mean kVp was 68 , mean mAs was 24 , mean FSD was 77.9 cm, mean ESAK was 1.11 mGy, and mean ESD was 1.52 mGy. At thickness 16-17 cm number of male and female patients were 1 and 0, mean weight was 64 kg., mean kVp was 75 , mean mAs was 24 , mean FSD was 74.3 cm, mean ESAK was 1.54 mGy, and mean ESD was 2.14 mGy. At thickness 18-19 cm there was no data, as shown in Table 4.7

Table 4.7 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in skull LAT projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-15	1/1	51	68	24	77.9	1.11	1.52
16-17	1/0	64	75	24	74.3	1.54	2.14
18-19	-	-	-	-	-	-	-
	2/1=3		*65-75				

Data from Room EMS, was patient information, exposure parameters, mean FSD, mean ESAK, and mean ESD for thickness range of each x-ray projection were shown in Table 4.8-4.14

For chest PA, thickness 14-18 cm.number of male and female patients were 2 and 3, mean weight was 57 kg. mean kVp was 122 , mean mAs was 3.5 , mean FSD was 161.2 cm, mean ESAK was 0.17 mGy, and mean ESD was 0.26 mGy. At thickness 19-23 cm number of male and female patients were 26 and 5, mean weight was 66 kg., mean kVp was 123 , mean mAs was 4.9 , mean FSD was 158.6 cm, mean ESAK was 0.25 mGy, and mean ESD was 0.38 mGy. At thickness 24-28 cm number of male and female patients were 1 and 0, mean weight was 70 kg., mean kVp was 122 , mean mAs was 5.0 , mean FSD was 154.6 cm, mean ESAK was 0.27 mGy, and mean ESD was 0.40 mGy as shown in Table 4.8

Table 4.8 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in chest PA projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-18	2/3	57	122	3.5	161.2	0.17	0.26
19-23	26/5	66	123	4.9	158.6	0.25	0.38
24-28	1/0	70	122	5.0	154.6	0.27	0.40
	29/8=37		*125				

For abdomen AP, thickness 15-20 cm. number of male and female patients were 17 and 8, mean weight was 60 kg., mean kVp was 76, mean mAs was 32 , mean FSD was 74.1cm, mean ESAK was 1.90 mGy, and mean ESD was 2.66 mGy. At thickness 21-26 cm number of male and female patients were 10 and 0, mean weight was 61 kg., mean kVp was 79 , mean mAs was 34, mean FSD was 71.5 cm, mean ESAK was 2.35 mGy, and mean ESD was 3.31 mGy. At thickness 27-32 cm, there was no data, as shown in Table 4.9

Table 4.9 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in abdomen AP projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
15-20	17/8	60	76	32	74.1	1.90	2.66
21-26	10/0	61	79	34	71.5	2.35	3.31
27-32	-	-	-	-	-	-	-
	27/8=35		*75-80				

For cervical spine AP, thickness 8-9 cm. number of male and female patients were 0 and 2, mean weight was 63 kg., mean kVp was 65 , mean mAs was 7 , mean FSD was 84.3 cm, mean ESAK was 0.19 mGy and mean ESD was 0.25 mGy At thickness 10-11 cm number of male and female patients were 5 and 2, mean weight was 64 kg., mean kVp was 70 , mean mAs was 7 , mean FSD was 82.4 cm, mean ESAK was 0.27 mGy, and mean ESD was 0.37 mGy At thickness 12-13 cm there was no data, as shown in Table 4.10

Table 4.10 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in cervical spine AP projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
8-9	0/2	63	65	7	84.3	0.19	0.25
10-11	5/2	64	70	7	82.4	0.27	0.37
12-13	-	-	-	-	-	-	-
	5/4=9		*65-70				

For lumbar spine AP, thickness 15-20 cm. number of male and female patients were 5 and 7, mean weight was 61 kg., mean kVp was 77 , mean mAs was 24 , mean FSD was 74.2 cm, mean ESAK was 1.35 mGy, and mean ESD was 1.89 mGy. At thickness 21-26 cm number of male and female patients were 4 and 0, mean weight was 71 kg., mean kVp was 81 , mean mAs was 30 , mean FSD was 71.9 cm, mean ESAK was 2.2 mGy, and mean ESD was 3.10 mGy At thickness 27-32 cm, there was no data, as shown in Table 4.11

Table 4.11 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in lumbar spine AP projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
15-20	5/7	61	77	24	74.2	1.35	1.89
21-26	4/0	71	81	30	71.9	2.2	3.10
27-32	-	-	-	-	-	-	-
	9/7=16		*75-85				

For lumbar spine LAT, thickness 18-21 cm. there was no data. At thickness 22-25 cm number of male and female patients were 8 and 4, mean weight was 62 kg., mean kVp was 90 , mean mAs was 55 , mean FSD was 68.7 cm, mean ESAK was 5.59 mGy, and mean ESD was 8.05 mGy. At thickness 26-29 cm number of male and female patients were 3 and 4, mean weight was 73 kg., mean kVp was 90, mean mAs was 59, mean FSD was 65.9 cm, mean ESAK was 6.99 mGy, and mean ESD was 10.06 mGy as shown in Table 4.12

Table 4.12 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in lumbar spine LAT projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
18-21	-	-	-	-	-	-	-
22-25	8/4	62	90	55	68.7	5.59	8.05
26-29	3/4	73	90	59	65.9	6.99	10.06
	11/8=19		*90				

For skull PA, thickness 14-15 cm number of male and female patients were 0 and 1, mean weight was 46 kg, mean kVp was 70, mean mAs was 24, mean FSD was 78.0 cm., mean ESAK was 1.03 mGy, and mean ESD was 1.42 mGy, At thickness 16-17 cm number of male and female patients were 2 and 0, mean weight was 67 kg., mean kVp was 73 , mean mAs was 24 , mean FSD was 76.3 cm, mean ESAK was 1.10 mGy, and mean ESD was 1.65 mGy. At thickness 18-19 cm, there was no data as shown in Table 4.13

Table 4.13 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in skull PA projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-15	0/1	46	70	24	78.0	1.03	1.42
16-17	2/0	67	73	24	76.3	1.10	1.65
18-19	-	-	-	-	-	-	-
	2/1=3		*70-75				

For skull LAT, thickness 14-15 cm there was no data. At thickness 16-17 cm number of male and female patients were 1 and 1, mean weight was 59 kg, mean kVp was 73 , mean mAs was 23 , mean FSD was 76.5 cm, mean ESAK was 1.14 mGy, and mean ESD was 1.58 mGy At thickness 18-19 cm, there was no data as shown in Table 4.14

Table 4.14 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in skull LAT projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-15	-	-	-	-	-	-	-
16-17	1/1	59	73	23	76.5	1.14	1.58
18-19	-	-	-	-	-	-	-
	1/1=2		*70-75				

4.2.2 Patient image quality grading

Image quality data were analyzed by two radiologists from CR images on the monitor of the workstation into A-grade clearly accept, B-grade accept with some remarks and C-grade reject. The number of images depended on sample size of selected projections, Chest PA was 72, Abdomen AP was 58, Cervical spine AP was 18, Lumbar spine AP was 31, Lumbar spine LAT was 39, Skull PA was 6 and Skull LAT was 5. The image quality was defined according to EU image evaluation criteria (Appendix B). Images were graded by two radiologists, R1 was the first radiologist and R2 was the second radiologist, and divided into two rooms, Room No.4 and Room EMS, as shown in Table 4.15

For Room No.4, image quality grading by the first radiologist (R1) on chest PA, thickness 14-18 cm. A-grade was 4 images. B-grade was 1 image which caused from positioning 1 image. At thickness 19-23 cm. A-grade was 19 images. B-grade was 5 images which caused from over exposure 1 image and artifact 4 images. At thickness 24-28 cm. A-grade was 5 images. B-grade was 1 image which caused from positioning 1 image The total of A-grade was 80% and B-grade was 20%

For abdomen AP, thickness 15-20 cm. A-grade was 5 images. B-grade was 4 images which caused from positioning 2 images, over exposure 1 image and artifact was 1 image. At thickness 21-26 cm. A-grade was 9 images. B-grade was 5 images which caused from artifact 2 images, over exposure 1 image and positioning 2 images. At thickness 27-32 cm there was not data. The total of A-grade was 60.8% and B-grade was 39.2%

For cervical spine AP, thickness 8-9 cm. B-grade was 3 images which caused from under exposure 3 images. At thickness 10-11 cm. A-grade was 1 image. B-grade was 6 images which caused from under exposure 6 images. At thickness 12-13 cm. B-grade was 1 image which caused from under exposure 1 image. The total of A-grade was 11.1% and B-grade was 88.9%

For lumbar spine AP, thickness 15-20 cm. A-grade was 6 images. B-grade was 3 images which caused from under exposure 3 images. At thickness 21-26 cm. A-grade was 4 images. B-grade was 2 images which caused from artifact 2 images. At thickness 27-32 cm. there was no data. The total of A-grade was 66.7% and B-grade was 33.3%

For lumbar spine LAT, thickness 18-21 cm. there was no data. At thickness 22-25 cm. A-grade was 9 images. B-grade was 4 images which caused from positioning 3 images and under exposure 1 image. At thickness 26-29 cm. A-grade was 4 images. B-grade was 3 images which caused from under exposure 2 images and artifact 1 image. The total of A-grade was 65% and B-grade was 35%

For skull PA, thickness 14-15 cm. B-grade was 1 image which caused from positioning 1 image. At thickness 16-17 cm. A-grade was 1 image. At thickness 18-19 cm A-grade was 1 image. The total of A-grade was 66.7% and B-grade was 33.3%

For skull LAT, thickness 14-15 cm A-grade was 2 images. At thickness 16-17 cm. B-grade was 1 image which caused from positioning 1 image. At thickness 18-19 cm there was no data. The total of A-grade was 66.7% and B-grade was 33.3%

Number image of selected projections grading into A, B and C grade by the second radiologist (R2) was the same as the first radiologist in chest PA, abdomen AP, cervical spine AP, lumbar spine AP, lumbar spine LAT, skull PA and skull LAT, as shown in Table 4.15. There was no C-grade image by both radiologists.

Table 4.15 Grading images by two radiologists, R1 and R2 from *Room No.4*

Projection	Thickness (cm.)	R1			Causes	R2			Causes
		Image Grading				Image Grading			
		A	B*	C		A	B*	C	
Chest PA	14-18	4	1	-	* Position = 1	4	1	-	* Position = 1
	19-23	19	5	-	*Artifact =4, Over exp.=1	19	5	-	*Artifact =4, Over exp.=1
	24-28	5	1	-	* Position = 1	5	1	-	* Position = 1
Total (%)		80	20	-		80	20		
Abdomen AP	15-20	5	4	-	* Position =2, Artifact = 1, Over exp.=1	5	4	-	* Position =2, Artifact = 1, Over exp.=1
	21-26	9	5	-	* Artifact = 2, Position = 2, Over exp.=1	9	5	-	* Artifact = 2, Position = 2, Over exp.=1
	27-32	-	-	-	-	-	-	-	-
Total (%)		60.8	39.2			60.8	39.2		
Cervical spine AP	8-9	0	1	-	*Under exp.=1	0	1	-	* Under exp.=1
	10-11	1	6	-	*Under exp.=6	1	6	-	* Under exp.=6
	12-13	0	1	-	*Under exp.=1	0	1	-	* Under exp.=1
Total (%)		11.1	88.9	-		11.1	88.9	-	
Lumbar spine AP	15-20	6	3	-	*Under exp.= 3	6	3	-	*Under exp.= 3
	21-26	4	2	-	* Artifact = 2	4	2	-	* Artifact = 2
	27-32	-	-	-	-	-	-	-	-
Total (%)		66.7	33.3	-		66.7	33.3	-	
Lumbar spine LAT	18-21	-	-	-	-	-	-	-	-
	22-25	9	4	-	* Position.=3, Under exp.=1	9	4	-	* Position.=3, Under exp.=1
	26-29	4	3	-	*Under exp.= 2 Artifact =1	4	3	-	*Under exp.= 2 Artifact =1
Total (%)		65	35	-		65	35	-	
Skull PA	14-15	0	1	-	* Position = 1	0	1	-	* Position = 1
	16-17	1	0	-	-	1	0	-	-
	18-19	1	0	-	-	1	0	-	-
Total (%)		66.7	33.3	-		66.7	33.3	-	
Skull LAT	14-15	2	0	-	-	2	0	-	-
	16-17	0	1	-	* Position = 1	0	1	-	* Position = 1
	18-19	-	-	-	-	-	-	--	-
Total (%)		66.7	33.3	-		66.7	33.3	-	

For Room EMS, image quality grading by the first radiologist (R1) on chest PA, thickness 14-18 cm. A-grade was 4 images and B-grade was 1 image which caused from positioning 1 image. At thickness 19-23 cm. A-grade was 26 images. B-grade was 5 images which caused from positioning 5 images. At thickness 24-28 cm. A-grade was 1 image. The total of A-grade was 83.8% and B-grade was 16.2%

For abdomen AP, thickness 15-20 cm. A-grade was 15 images. B-grade was 10 images which caused from positioning 6 images and artifact was 4 images. At thickness 21-26 cm. A-grade was 8 images. B-grade was 2 images which caused from artifact 2 images. At thickness 27-32 cm there was not data. The total of A-grade was 65.7% and B-grade was 34.3%

For cervical spine AP, thickness 8-9 cm. A-grade was 1 image and B-grade was 1 image which caused from under exposure 1 image. At thickness 10-11 cm. A-grade was 1 image. B-grade was 6 images which caused from under exposure 5 images and positioning 1 image. At thickness 12-13 cm, there was no data. The total of A-grade was 22.2% and B-grade was 77.8%

For lumbar spine AP, thickness 15-20 cm. A-grade was 9 images. B-grade was 3 images which caused from under exposure 3 images. At thickness 21-26 cm. A-grade was 4 images. At thickness 27-32 cm. there was no data. The total of A-grade was 81.3% and B-grade was 18.7%

For lumbar spine LAT, thickness 18-21 cm. there was no data. At thickness 22-25 cm. A-grade was 12 images. At thickness 26-29 cm. A-grade was 2 images. B-grade was 5 images which caused from positioning 5 images. The total of A-grade was 73.7% and B-grade was 26.3%

For skull PA, thickness 14-15 cm. B-grade was 1 image which caused from positioning 1 image. At thickness 16-17 cm. A-grade was 1 image and B-grade was 1 image which caused from positioning 1 image. At thickness 18-19 cm, there was no data. The total of A-grade was 33.3% and B-grade was 66.7%

For skull LAT, thickness 14-15 cm, there was no data. At thickness 16-17 cm. A-grade was 1 image. B-grade was 1 image which caused from positioning 1 image. At thickness 18-19 cm there was no data. The total of A-grade was 50% and B-grade was 50%

Number image of selected projections grading into A, B and C grade by the second radiologist (R2) was the same as the first radiologist in chest PA, abdomen AP, cervical spine AP, lumbar spine AP, lumbar spine LAT, skull PA and skull LAT, as shown in Table 4.16. There was no C-grade image by both radiologists

Table 4.16 Grading images by two radiologists, R1 and R2 from *Room EMS*

Projection	Thickness (cm.)	R1			Causes	R2			Causes
		Image Grading				Image Grading			
		A	B*	C		A	B*	C	
Chest PA	14-18	4	1	-	*Position =1	4	1	-	*Position =1
	19-23	26	5	-	*Position =5	26	5	-	*Position =5
	24-28	1	0	-	-	1	0	-	-
Total (%)		83.8	16.2			83.8	16.2		
Abdomen AP	15-20	15	10	-	*Position =6, Artifact = 4	15	10	-	*Position =6, Artifact = 4
	21-26	8	2	-	*Artifact = 2	8	2	-	*Artifact = 2
	27-32	-	-	-	-	-	-	-	-
Total (%)		65.7	34.3			65.7	34.3		
Cervical spine AP	8-9	1	1	-	*Under exp.=1	1	1	-	*Under exp=1
	10-11	1	6	-	*Under exp.=6	1	6	-	*Under exp=6
	12-13	-	-	-	-	-	-	-	-
Total (%)		22.2	77.8			22.2	77.8		
Lumbar spine AP	15-20	9	3	-	*Under exp.=3	9	3	-	*Under exp=3
	21-26	4	0	-	-	4	0	-	-
	27-32	-	-	-	-	-	-	-	-
Total (%)		81.3	18.7			81.3	18.7		

Lumbar spine LAT	18-21	-	-	-	-	-	-	-	-
	22-25	12	0	-	-	12	0	-	-
	26-29	2	5	-	*Position = 5	2	5	-	*Position = 5
Total (%)		73.7	26.3			73.7	26.3		
Skull PA	14-15	0	1	-	*Position = 1	0	1	-	*Position = 1
	16-17	1	1	-	*Position = 1	1	1	-	*Position = 1
	18-19	-	-	-	-	-	-	-	-
Total (%)		33.3	66.7			33.3	66.7		
Skull LAT	14-15	-	-	-	-	-	-	-	-
	16-17	1	1	-	*Position = 1	1	1	-	*Position = 1
	18-19	-	-	-	-	-	-	-	-
Total (%)		33.3	66.7			33.3	66.7		

4.2.3 Retake analysis

Film retake collection from two x-ray rooms, Room No. 4 and Room EMS, was conducted within one month. General films such as orthopaedic, neck and KUB films were included.

The total number of examinations from Room No.4 was 1,488 with 51 retakes(3.4%) and the causes from patient positioning 30 images(58.8%), motion 12 images (23.5%), artifact 5 images (9.8%), and others (exposure error) 4 images (7.9%) as shown in Table 4.17

The total number of examinations from Room EMS was 2,751 with 75 retakes (2.7%) and the causes from patient positioning 50 images(66.7%), motion 6 images(8%), artifact 2 images(2.7%), Field size misplacement 6 images(8%) and others (exposure error) 11 images(14.6%) as shown in Table 4.18

Table 4.17 Retake rate analysis of *Room No.4 before training program*

Time period of the analysis(mm-yy)	From 01-04-2008 to 30-04-2008	
At the level of **Radiological technologist** (code 210)		
Number of image during 1 month	1,488	
Number of image rejected by radiological technologist	51	
Percent of image reject by radiological technologist	3.4	
Cause analysis of retake	Number	Percent
__ Patient positioning	30	58.8
__ Motion	12	23.5
__ Artifacts	5	9.8
__ Field size misplacement	-	
__ Others (exposure error)	4	7.9
Total	51	100

Table 4.18 Retake analysis of *Room EMS before the training program*

Time period of the analysis(mm-yy)	From 01-04-2008 to 30-04-2008	
At the level of **Radiological technologist** (code 205)		
Number of image during 1 month	2,751	
Number of image rejected by radiological technologist	75	
Percent of image reject by radiological technologist	2.7	
Cause analysis of retake	Number	Percent
__ Patient positioning	50	66.7
__ Motion	6	8
__ Artifacts	2	2.7
__ Field size misplacement	6	8
__ Others (exposure error, incorrect patient)	11	14.6
Total	75	100

4.3 Training program

The training program was held on 22 May 2008 of the title of "Optimization of Radiation Dose and Image Quality on CR Image in Routine Simple Projections" at Rajavithi Hospital. There were 19 participants who were radiological technologists and radiological staffs participation the program. The assessment course of the Multiple Choice Questions (MCQs) arranged at before and after the training program (Appendix C). The score of the MCQs test from the participants are shown in Table 4.19 which an average score of 3.3(33%) for pre test and 6.2 (62.1%) for post test. The full score was 10 and testing time was 15 mins.

Table 4.19 Comparison MCQs scores of the participants between before and after the training program

No. of participants	Pre-test	Post-test	No. of participants	Pre-test	Post-test
1	3	6	11	1	5
2	4	-	12	5	10
3	4	8	13	4	8
4	6	8	14	3	9
5	1	5	15	3	5
6	0	5	16	2	4
7	2	5	17	3	2
8	2	4	18	0	2
9	4	6	19	10	10
10	6	10	average	3.3	6.2
			percent	33	62.1

4.4 Patients dose, image quality grading and retake analysis after the equipment QC and the training program

4.4.1 Patients dose

After training program, data was also separated into two rooms, Room No.4 and Room EMS in totally 229 patients as the same number as before training program. Data from Room No.4 was patient information, exposure parameters, mean FSD, mean ESAK, and mean ESD for thickness range of each x-ray projection were shown in Table 4.20-4.26

For chest PA, thickness 14-18 cm. number of male and female patients were 2 and 7, mean weight was 49 kg., mean kVp was 120 , mean mAs was 2.7 , mean FSD was 162.4 cm, mean ESAK was 0.09 mGy, and mean ESD was 0.14 mGy. At thickness 19-23 cm number of male and female patients were 8 and 21, mean weight was 64 kg., mean kVp was 120 , mean mAs was 3.8 , mean FSD was 158.5 cm, mean ESAK was 0.11 mGy, and mean ESD was 0.17 mGy. At thickness 24-28 cm number of male and female patients were 2 and 1, mean weight was 76 kg., mean kVp was 120 , mean mAs was 4, mean FSD was 154.1 cm, mean ESAK was 0.15 mGy, and mean ESD was 0.22 mGy as shown in Table 4.1

Table 4.20 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in Chest PA projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-18	2/7	49	120	2.7	162.4	0.09	0.14
19-23	8/21	64	120	3.8	158.5	0.11	0.17
24-28	2/1	76	120	4	154.1	0.15	0.22
	12/29=41		*120				

For abdomen AP, thickness 15-20 cm. number of male and female patients were 6 and 8, mean weight was 57 kg., mean kVp was 81, mean mAs was 24, mean FSD was 74.2 cm, mean ESAK was 1.82 mGy, and mean ESD was 2.57 mGy. At thickness 21-26 cm number of male and female patients were 6 and 8, mean weight was 68 kg., mean kVp was 83 , mean mAs was 27, mean FSD was 69.5 cm, mean ESAK was 2.49 mGy, and mean ESD was 3.52 mGy. At thickness 27-32 cm number of male and female patients were 1 and 0, mean weight was 95 kg., mean kVp was 85 , mean mAs was 30, mean FSD was 65.3 cm, mean ESAK was 3.24 mGy, and mean ESD was 4.6 mGy as shown in Table 4.21

Table 4.21 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in abdomen AP projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
15-20	6/8	57	81	24	74.2	1.82	2.57
21-26	6/8	68	83	27	69.5	2.49	3.52
27-32	1/0	95	85	30	65.3	3.24	4.6
	13/16=29		*80-85				

For cervical spine AP, thickness 8-9 cm. number of male and female patients were 1 and 2, mean weight was 54 kg., mean kVp was 60, mean mAs was 6, mean FSD was 83.8 cm, mean ESAK was 0.17 mGy, and mean ESD was 0.23 mGy. At thickness 10-11 cm number of male and female patients were 0 and 4, mean weight was 59 kg., mean kVp was 63 , mean mAs was 6 , mean FSD was 82.4 cm, mean ESAK was 0.26 mGy, and mean ESD was 0.27 mGy. At thickness 12-13 cm number of male and female patients were 1 and 1, mean weight was 60 kg., mean kVp was 63 , mean mAs was 7 , mean FSD was 80.8 cm, mean ESAK was 0.25 mGy, and mean ESD was 0.34 mGy as shown in Table 4.3

Table 4.22 Patients information, exposure parameters mean FSD, mean ESAK, and mean ESD in cervical spine AP projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
8-9	1/2	54	60	6	83.8	0.17	0.23
10-11	0/4	59	63	6	82.4	0.26	0.27
12-13	1/1	60	63	7	80.8	0.25	0.34
	2/7=9		*60-65				

For lumbar spine AP, thickness 15-20 cm. number of male and female patients were 3 and 5, mean weight was 58 kg., mean kVp was 83 , mean mAs was 20 , mean FSD was 73.6 cm, mean ESAK was 1.62 mGy, and mean ESD was 2.30 mGy. At thickness 21-26 cm number of male and female patients were 1 and 6, mean weight was 67 kg., mean kVp was 84 , mean mAs was 24 , mean FSD was 69.6 cm, mean ESAK was 2.28 mGy, and mean ESD was 3.24 mGy. At thickness 27-32 cm, there was no data, as shown in Table 4.23

Table 4.23 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in lumbar spine AP projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
15-20	3/5	58	83	20	73.6	1.62	2.30
21-26	1/6	67	84	24	69.6	2.28	3.24
27-32	-	-	-	-	-	-	-
	4/11=15		*80-85				

For lumbar spine LAT, thickness 18-21 cm. number of male and female patients were 1 and 0, mean weight was 52 kg., mean kVp was 85 , mean mAs was 45 , mean FSD was 72.8 cm, mean ESAK was 4.34 mGy, and mean ESD was 6.61 mGy.. At thickness 22-25 cm number of male and female patients were 0 and 9, mean weight was 53 kg., mean kVp was 87 , mean mAs was 52 , mean FSD was 69.4 cm, mean ESAK was 5.22 mGy, and mean ESD was 7.47 mGy. At thickness 26-29 cm number of male and female patients were 4 and 5, mean weight was 66 kg., mean kVp was 90 , mean mAs was 55, mean FSD was 65.9 cm, mean ESAK was 6.60 mGy, and mean ESD was 9.50 mGy as shown in Table 4.24

Table 4.24 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in lumbar spine LAT projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
18-21	1/0	52	85	45	72.8	4.34	6.61
22-25	0/9	53	87	52	69.4	5.22	7.47
26-29	4/5	66	90	55	65.9	6.60	9.50
	5/14=19		*85-90				

For skull PA, thickness 14-15 cm. there was no data. At thickness 16-17 cm number of male and female patients were 0 and 2, mean weight was 51 kg., mean kVp was 65 , mean mAs was 24 , mean FSD was 75.6 cm, mean ESAK was 1.26 mGy, and mean ESD was 1.72 mGy. At thickness 18-19 cm number of male and female patients were 1 and 0, mean weight was 72 kg., mean kVp was 65 , mean mAs was 24 , mean FSD was 73.8 cm, mean ESAK was 1.32 mGy, and mean ESD was 1.80 mGy as shown in Table 4.25

Table 4.25 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in skull PA projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-15	-	-	-	-	-	-	-
16-17	0/2	51	65	24	75.6	1.26	1.72
18-19	1/0	72	65	24	73.8	1.32	1.80
	1/2=3		*65				

For skull LAT, thickness 14-15 cm number of male and female patients were 1 and 0 mean weight was 56 kg., mean kVp was 65 , mean mAs was 24 , mean FSD was 77.5 cm, mean ESAK was 0.81 mGy, and mean ESD was 1.09 mGy. At thickness 16-17 cm number of male and female patients were 2 and 0, mean weight was 70 kg., mean kVp was 65 , mean mAs was 24 , mean FSD was 76.5 cm, mean ESAK was 0.83 mGy, and mean ESD was 1.12 mGy. At thickness 18-19 cm there was no data, as shown in Table 4.26

Table 4.26 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in skull LAT projection from *Room No.4* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-15	1/0	56	65	24	77.5	0.81	1.09
16-17	2/0	70	65	24	76.5	0.83	1.12
18-19	-	-	-	-	-	-	-
	3/0=3		*65				

Data from Room EMS was patient information, exposure parameters, mean FSD, mean ESAK, and mean ESD for thickness range of each x-ray projection were shown in Table 4.27-4.33

For chest PA, thickness 14-18 cm. number of male and female patients were 6 and 4, mean weight was 53 kg. mean kVp was 120 , mean mAs was 3.2 , mean FSD was 162.0 cm, mean ESAK was 0.13 mGy, and mean ESD was 0.20 mGy. At thickness 19-23 cm number of male and female patients were 19 and 1, mean weight was 62 kg., mean kVp was 120 , mean mAs was 4.1 , mean FSD was 159.5 cm, mean ESAK was 0.17 mGy, and mean ESD was 0.26 mGy. At thickness 24-28 cm number of male and female patients were 0 and 1, mean weight was 70 kg., mean kVp was 120 , mean mAs was 6.1 , mean FSD was 156.1 cm, mean ESAK was 0.26 mGy, and mean ESD was 0.40 mGy as shown in Table 4.27

Table 4.27 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in chest PA projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-18	6/4	53	120	3.2	162.0	0.13	0.20
19-23	19/1	62	120	4.1	159.5	0.17	0.26
24-28	0/1	70	120	6.1	156.1	0.26	0.40
	25/6=31		*120				

For abdomen AP, thickness 15-20 cm. number of male and female patients were 7 and 18, mean weight was 56 kg., mean kVp was 81, mean mAs was 27 , mean FSD was 74.6 cm, mean ESAK was 1.83 mGy, and mean ESD was 2.58 mGy. At thickness 21-26 cm number of male and female patients were 2 and 2, mean weight was 70 kg., mean kVp was 85 , mean mAs was 30, mean FSD was 70.9 cm, mean ESAK was 2.47 mGy, and mean ESD was 3.50 mGy. At thickness 27-32 cm, there was no data, as shown in Table 4.28

Table 4.28 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in abdomen AP projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
15-20	7/18	56	81	27	74.6	1.83	2.58
21-26	2/2	70	85	30	70.9	2.47	3.50
27-32	-	-	-	-	-	-	-
	9/20=29		*80-85				

For cervical spine AP, thickness 8-9 cm. there was no data. At thickness 10-11 cm number of male and female patients were 5 and 4, mean weight was 58 kg., mean kVp was 64 , mean mAs was 7 , mean FSD was 82.3 cm, mean ESAK was 0.24 mGy, and mean ESD was 0.33 mGy At thickness 12-13 cm there was no data, as shown in Table 4.29

Table 4.29 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in cervical spine AP projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
8-9	-	-	-	-	-	-	-
10-11	5/4	58	64	7	82.3	0.24	0.33
12-13	-	-	-	-	-	-	-
	5/4=9		*64				

For lumbar spine AP, thickness 15-20 cm. number of male and female patients were 8 and 6, mean weight was 58 kg., mean kVp was 80 , mean mAs was 23 , mean FSD was 74.3 cm, mean ESAK was 1.28 mGy, and mean ESD was 1.81 mGy. At thickness 21-26 cm number of male and female patients were 0 and 2, mean weight was 64 kg., mean kVp was 80 , mean mAs was 30 , mean FSD was 71.8 cm, mean ESAK was 2.14 mGy, and mean ESD was 3.01 mGy At thickness 27-32 cm, there was no data, as shown in Table 4.30

Table 4.30 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in lumbar spine AP projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
15-20	8/6	58	80	23	74.3	1.28	1.81
21-26	0/2	64	80	30	71.8	2.14	3.01
27-32	-	-	-	-	-	-	-
	8/8=16		*80				

For lumbar spine LAT, thickness 18-21 cm. number of male and female patients were 0 and 1, mean weight was 55 kg., mean kVp was 90, mean mAs was 50, mean FSD was 72.0 cm, mean ESAK was 4.58 mGy, and mean ESD was 6.60 mGy At thickness 22-25 cm number of male and female patients were 5 and 10, mean weight was 56 kg., mean kVp was 90 , mean mAs was 52 , mean FSD was 69.4 cm, mean ESAK was 5.18 mGy, and mean ESD was 7.46 mGy. At thickness 26-29 cm number of male and female patients were 2 and 2, mean weight was 60 kg., mean kVp was 90, mean mAs was 63, mean FSD was 66.8 cm, mean ESAK was 6.77 mGy, and mean ESD was 9.76 mGy as shown in Table 4.31

Table 4.31 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in lumbar spine LAT projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
18-21	0/1	55	90	50	72.0	4.58	6.60
22-25	5/10	56	90	52	69.4	5.18	7.46
26-29	2/2	60	90	63	66.8	6.77	9.76
	7/13=20		*90				

For skull PA, thickness 14-15 cm there was no data. At thickness 16-17 cm number of male and female patients were 1 and 0, mean weight was 60 kg., mean kVp was 65 , mean mAs was 26 , mean FSD was 75.5 cm, mean ESAK was 0.93 mGy, and mean ESD was 1.24 mGy. At thickness 18-19 cm. number of male and female patients were 2 and 0, mean weight was 61 kg, mean kVp was 65, mean mAs was 26, mean FSD was 74.5 cm., mean ESAK was 0.95 mGy, and mean ESD was 1.27 mGy, as shown in Table 4.32

Table 4.32 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in skull PA projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-15	-	-	-	-	-	-	-
16-17	1/0	60	65	26	75.5	0.93	1.24
18-19	2/0	61	65	26	74.5	0.95	1.27
	3/0=3		*65				

For skull LAT, thickness 14-15 cm. number of male and female patients were 0 and 1, mean weight was 55 kg, mean kVp was 70 , mean mAs was 24 , mean FSD was 77.8 cm, mean ESAK was 1.21 mGy, and mean ESD was 1.66 mGy At thickness 16-17 cm number of male and female patients were 1 and 0, mean weight was 72 kg, mean kVp was 70 , mean mAs was 24 , mean FSD was 76.8 cm, mean ESAK was 1.24 mGy, and mean ESD was 1.71 mGy At thickness 18-19 cm. there was no data as shown in Table 4.33

Table 4.33 Patients information, exposure parameters, mean FSD, mean ESAK, and mean ESD in skull LAT projection from *Room EMS* (* kVp range)

Thickness (cm.)	Male/ Female	Mean Weight (kg)	Mean kVp	Mean mAs	Mean FSD (cm)	Mean ESAK (mGy)	Mean ESD (mGy)
14-15	0/1	55	70	24	77.8	1.21	1.66
16-17	1/0	72	70	24	76.8	1.24	1.71
18-19	-	-	-	-	-	-	-
	1/1=2		*70				

4.4.2 Patient image quality grading

The image quality data were analyzed by two radiologists from CR images on the monitor of the workstation into A-grade accepted clearly, B-grade accepted with some remarks and C-grade rejected. The number of images depended on sample size of selected projections, Chest PA was 72, Abdomen AP was 58, Cervical spine AP was 18, Lumbar spine AP was 31 and Lumbar spine LAT was 39, Skull PA was 6 and Skull LAT was 5. The image quality was defined according to EU image evaluation criteria (Appendix B). Images were graded by two radiologists, R1 was the first radiologist and R2 was the second radiologist, and divided into two rooms, Room No.4 and Room EMS, as shown in Table 4.34

For Room No.4, image quality grading by the first radiologist (R1) on chest PA, thickness 14-18 cm. A-grade was 7 images. B-grade was 2 images which caused from over exposure 1 image and artifact 1 image. At thickness 19-23 cm. A-grade was 21 images. B-grade was 2 images which caused from over exposure 1 image and artifact 1

image. At thickness 24-28 cm. A-grade was 3 images. The total of A-grade was 87.6% and B-grade was 11.4%

For abdomen AP, thickness 15-20 cm. A-grade was 11 images. B-grade was 3 images which caused from positioning 3 images. At thickness 21-26 cm. A-grade was 7 images. B-grade was 1 image which caused from positioning 1 image. At thickness 27-32 cm. B-grade was 1 image which caused from positioning 1 image. The total of A-grade was 78.3% and B-grade was 21.7%

For cervical spine AP, thickness 8-9 cm. A-grade was 3 images. At thickness 10-11 cm. A-grade was 2 images. B-grade was 2 images which caused from positioning 2 images. At thickness 12-13 cm. A-grade was 2 images. The total of A-grade was 77.8% and B-grade was 22.2%

For lumbar spine AP, thickness 15-20 cm. A-grade was 8 images. At thickness 21-26 cm. A-grade was 7 images. At thickness 27-32 cm. there was no data. The total of A-grade was 100%.

For lumbar spine LAT, thickness 18-21 cm. A-grade was 1 image. At thickness 22-25 cm. A-grade was 9 images. B-grade was 1 image which caused from positioning 1 image. At thickness 26-29 cm. A-grade was 9 images. The total of A-grade was 95% and B-grade was 5%

For skull PA, thickness 14-15 cm. A-grade was 2 images. At thickness 16-17 cm. A-grade was 1 image. At thickness 18-19 cm there was no data. The total of A-grade was 100%.

For skull LAT, thickness 14-15 cm B-grade was 1 image which caused from positioning 1 image. At thickness 16-17 cm. A-grade was 2 images. At thickness 18-19 cm there was no data. The total of A-grade was 66.7% and B-grade was 33.3%

Number image of selected projections grading into A, B and C grade by the second radiologist (R2) was the same as the first radiologist in chest PA, cervical spine AP, lumbar spine AP, lumbar spine LAT, skull PA and skull LAT as shown in Table 4.34. There was no C-grade image by two radiologists.

Table 4.34 Grading images by two radiologists, R1 and R2 from *Room No.4*

Projection	Thickness (cm.)	R1			Causes	R2			Causes
		Image Grading				Image Grading			
		A	B*	C		A	B*	C	
Chest PA	14-18	7	2	-	*Over exp. =1, Artifact =1	7	2	-	*Over exp. =1, Artifact =1
	19-23	21	2	-	*Over exp. =1, Artifact =1	21	2	-	*Over exp. =1, Artifact =1
	24-28	3	0		-	3	0		-
Total (%)		87.6	11.4			87.6	11.4		
Abdomen AP	15-20	11	3	-	*Position =3	11	3	-	*Position =3
	21-26	7	1	-	*Position =1	7	1	-	*Position =1
	27-32	0	1		*Position =1	0	1	-	*Position =1
Total (%)		78.3	21.7			78.3	21.7		
Cervical spine AP	8-9	3	0	-	-	3	0	-	-
	10-11	2	2	-	*Position =2	2	2	-	*Position =2
	12-13	2	0		-	2	0	-	-
Total (%)		77.8	22.2			77.8	22.2		

Lumbar spine AP	15-20	8	0	-		8	0	-	
	21-26	7	0	-	-	7	0	-	
	27-32	-	-	-	-	-	-	-	
Total (%)		100	0			100	0		
Lumbar spine LAT	18-21	1	0	-	-	1	0	-	-
	22-25	9	1	-	* Position =1	9	1	-	* Position =1
	26-29	9	0	-	-	9	0	-	-
Total (%)		95	5			95	5		
Skull PA	14-15	2	0	-	-	2	0	-	
	16-17	1	0	-	-	1	0	-	
	18-19	-	-	-	-	-	-	-	
Total (%)		94.7	5.3			94.7	5.3		
Skull LAT	14-15	0	1	-	* Position =1	0	1	-	* Position =1
	16-17	2	0	-	-	2	0	-	-
	18-19	-	-	-	-	-	-	-	-
Total (%)		66.6	33.3			66.6	33.3		

For Room EMS, image quality grading by the first radiologist (R1) on chest PA, thickness 14-18 cm. A-grade was 9 images and B-grade was 1 image which caused from positioning 1 image. At thickness 19-23 cm. A-grade was 26 images. At thickness 24-28 cm. A-grade was 1 image. The total of A-grade was 97.3% and B-grade was 2.7%

For abdomen AP, thickness 15-20 cm. A-grade was 23 images B-grade was 4 images which caused from positioning 3 images and under exposure was 1 image. At thickness 21-26 cm. A-grade was 8 images. At thickness 27-32 cm there was not data. The total of A-grade was 88.6% and B-grade was 11.4%

For cervical spine AP, thickness 8-9 cm. there was not data. At thickness 10-11 cm. A-grade was 7 images. B-grade was 2 images which caused from positioning 1 image and under exposure 1 image. At thickness 12-13 cm, there was no data. The total of A-grade was 77.8% and B-grade was 22.2%

For lumbar spine AP, thickness 15-20 cm. A-grade was 14 images. At thickness 21-26 cm. A-grade was 2 images. At thickness 27-32 cm. there was no data. The total of A-grade was 100%.

For lumbar spine LAT, thickness 18-21 cm. B-grade was 1 image which caused from positioning 1 image. At thickness 22-25 cm. A-grade was 12 images. B-grade was 2 images which caused from positioning 2 images. At thickness 26-29 cm. A-grade was 3 images. B-grade was 1 image which caused from under exposure 1 image. The total of A-grade was 78.9% and B-grade was 21.1%

For skull PA, thickness 14-15 cm. there was no data. At thickness 16-17 cm. A-grade was 1 image. At thickness 18-19 cm. A-grade was 2 images. The total of A-grade was 100%.

For skull LAT, thickness 14-15 cm. A-grade was 1 image. At thickness 16-17 cm. A-grade was 1 image. At thickness 18-19 cm there was no data. The total of A-grade was 100%.

Number image of selected projections grading into A, B and C grade by the second radiologist (R2) was the same as the first radiologist in these projections, chest PA, abdomen AP, cervical spine AP, lumbar spine AP, lumbar spine LAT, skull PA and skull LAT, as shown in Table 4.35. There was no C-grade image by two radiologists.

Table 4.35 Grading images by two radiologists, R1 and R2 from *Room EMS*

Projection	Thickness (cm.)	R1			Causes	R2			Causes
		Image Grading				Image Grading			
		A	B*	C		A	B*	C	
Chest PA	14-18	9	1	-	* Position =1	9	1	-	* Position =1
	19-23	26	0	-	-	26	0	-	-
	24-28	1	0	-	-	1	0	-	-
Total (%)		97.3	2.7			97.3	2.7		
Abdomen AP	15-20	23	4	-	* Position =3, Under exp.=1	23	4	-	* Position =3, Under exp.=1
	21-26	8	0	-	-	8	0	-	-
	27-32	-	-	-	-	-	-	-	-
Total (%)		88.6	11.4			88.6	11.4		
Cervical spine AP	8-9	-	-	-	-	-	-	-	-
	10-11	7	2	-	* Position =1, Under exp.=1	7	2	-	* Position =1, Under exp.=1
	12-13	-	-	-	-	-	-	-	-
Total (%)		77.8	22.2			77.8	22.2		
Lumbar spine AP	15-20	14	0	-	-	14	0	-	
	21-26	2	0	-	-	2	0	-	
	27-32	-	-	-	-	-	-	-	
Total (%)		100	0			100	0		
Lumbar spine LAT	18-21	0	1	-	* Position =1	0	1	-	* Position =1
	22-25	12	2	-	* Position =2	12	2	-	* Position =2
	26-29	3	1	-	*Under exp.=1	3	1	-	* Under exp.=1
Total (%)		78.9	21.1			78.9	21.1		
Skull PA	14-15	-	-	-	-	-	-	-	
	16-17	1	0	-	-	1	0	-	
	18-19	2	0	-	-	2	0	-	
Total (%)		100	0			100	0		
Skull LAT	14-15	1	0	-	-	1	0	-	
	16-17	1	0	-	-	1	0	-	
	18-19	-	-	-	-	-	-	-	
Total (%)		100	0			100	0		

4.4.3 Retake analysis

The total number of examinations from Room No.4 was 2,668 with retakes 66 (2.5%) and the causes from patient positioning 34 images (51.5%), motion 7 images (10.6%), artifact 13 images (19.7%) field size misplacement 10 images (15.2%) and others (exposure error) 2 images (3%) as shown in Table 4.36

The total number of examinations from EMS room was 2,905 with 72 retakes (2.5%) and the causes from patient positioning 58 images(80.5%), motion 4 images(5.6%), artifact 3 images(4.2%), Field size misplacement 2 images(2.8%) and others (exposure error) 5 images(6.9%) as shown in Table 4.37

Table 4.36 Retake analysis of *Room No.4 after training program*

Time period of the analysis(mm-yy)	From 01-06-2008 to 30-06-2008	
At the level of **Radiological technologist** (code 210)		
Number of image during 1 month	2,668	
Number of image rejected by radiological technologist	66	
Percent of image reject by radiological technologist	2.5	
Cause analysis of retake	Number	Percent
__ Patient positioning	34	51.5
__ Motion	7	10.6
__ Artifacts	13	19.7
__ Field size misplacement	10	15.2
__ Others (exposure error)	2	3.0
Total	66	100

Table 4.37 Retake rate analysis of *Room EMS after training program*

Time period of the analysis(mm-yy)	From 01-06-2008 to 30-06-2008	
At the level of **Radiological technologist** (code 205)		
Number of image during 1 month	2,905	
Number of image rejected by radiological technologist	72	
Percent of image reject by radiological technologist	2.5	
Cause analysis of retake	Number	Percent
__ Patient positioning	58	80.5
__ Motion	4	5.6
__ Artifacts	3	4.2
__ Field size misplacement	2	2.8
__ Others (exposure error)	5	6.9
Total	72	100

4.5 Comparison patient dose and image quality between before and after training program

To analyze data using application software SPSS version 16 for window, the descriptive and paired T-test were used.

4.5.1 Comparison patient dose between before and after the training program

To use Kolmogorov-Smimov Z function from SPSS version 16 in order to test the distribution of two group data (before and after the training), it indicated that all the value of asymmetric parameter significant (Appendix F) were more than 0.05 (α = 0.05). Therefore, the distribution of all data on both before and after the training

program was normal. Patient doses were matched by using similarity of body part thickness in centimeter of the same examination type. Mean ESD in mGy was compared in each projection from room by room. Mean ESD of patients' Room No.4 were compared with mean ESD of patients' Room No.4 in the period of before training and mean ESD of patients' Room EMS were compared with mean ESD of patients' Room EMS as the same period of before training. For the period after the training program, mean ESD were also compared in the same method as before training program as shown in Table 4.38-4.39.

Table 4.38, chest PA from Room No.4, before the training program, the mean ESD (mGy) and range in parenthesis was 0.23(0.15-0.39), SD was 0.06, third quartile was 0.27, after the training program the mean ESD (mGy) and range in parenthesis was 0.17(0.11-0.23), SD was 0.04, third quartile was 0.20, DRLs (IAEA) was 0.4, P-value was 0.00 and percent of dose reduction was 26.1.

Abdomen AP from Room No.4, before the training program, the mean ESD (mGy) and range in parenthesis was 3.34(2.06-5.23), SD was 0.99, third quartile was 4.03, after the training program the mean ESD (mGy) and range in parenthesis was 3.03(2.0-4.06), SD was 0.72, third quartile was 3.39, DRLs (IAEA) was 10, P-value was 0.11and percent of dose reduction was 9.3.

Cervical spine AP from Room No.4, before the training program, the mean ESD (mGy) and range in parenthesis was 0.32(0.24-0.45), SD was 0.07, third quartile was 0.37, after the training program the mean ESD (mGy) and range in parenthesis was 0.29(0.23-0.44), SD was 0.08, third quartile was 0.37, DRLs (IAEA) was not reported, P-value was 0.04and percent of dose reduction was 9.4.

Lumbar spine AP from Room No.4, before the training program, the mean ESD (mGy) and range in parenthesis was 3.02(2.08-5.36), SD was 0.95, third quartile was 3.38, after the training program the mean ESD (mGy) and range in parenthesis was 2.72(1.97-4.04), SD was 0.63, third quartile was 3.22, DRLs (IAEA) was 10, P-value was 0.23 and percent of dose reduction was 9.3.

Lumbar spine LAT from Room No.4, before the training program, the mean ESD (mGy) and range in parenthesis was 8.93(7.43-10.65), SD was 0.89, third quartile was 9.41, after the training program the mean ESD (mGy) and range in parenthesis was 8.32(6.16-11.36), SD was 1.59 third quartile was 8.8, DRLs (IAEA) was 30, P-value was 0.03and percent of dose reduction was 6.6.

Skull PA from Room No.4, before the training program, the mean ESD (mGy) and range in parenthesis was 1.94(1.83-2.13), SD was 0.17, third quartile was 1.97, after the training program the mean ESD (mGy) and range in parenthesis was 1.74(1.70-1.80), SD was 0.05, third quartile was 1.76, DRLs (IAEA) was 5, P-value was 0.11 nd percent of dose reduction was 9.8.

Skull LAT from Room No.4, before the training program, the mean ESD (mGy) and range in parenthesis was 1.71(1.40-2.14), SD was 0.38, third quartile was 1.89, after the training program the mean ESD (mGy) and range in parenthesis was 1.49 (1.66-1.71), SD was 0.34, third quartile was 1.70, DRLs (IAEA) was 3, P-value was 0.64 and percent of dose reduction was 1.7.

Table 4.38 Entrance skin dose, ESD(mGy), are shown in mean and range in parenthesis, SD and third quartile in comparison between before and after the training program of the same examination room (*Room No.4*), and DRLs(IAEA), P-value and percent of dose reduction.

Projections :No.4 room	Entrance Skin Dose, ESD (mGy)						DRLs (IAEA)	P-value	% dose reduction
	Before Training			After Training					
	Mean (min-max)	SD	3rd Quart.	Mean (min-max)	SD	3rd Quart.			
Chest PA	0.23 (0.15-0.39)	0.06	0.27	0.17 (0.11-0.23)	0.04	0.20	0.4	0.00	26.1
Abdomen AP	3.34 (2.06-5.23)	0.99	4.03	3.03 (2.0-4.60)	0.72	3.34	10	0.11	9.3
Cervical spine AP	0.32 (0.24-0.45)	0.07	0.37	0.29 (0.23-0.44)	0.08	0.37	-	0.04	9.4
Lumbar spine AP	3.02 (2.08-5.36)	0.95	3.38	2.72 (1.97-4.04)	0.63	3.22	10	0.23	9.3
LAT	8.93 (7.43-10.65)	0.89	9.41	8.32 (6.16-11.36)	1.59	8.8	30	0.03	6.6
Skull PA	1.94 (1.83-2.13)	0.17	1.97	1.74 (1.70-1.80)	0.05	1.76	5	0.11	9.8
LAT	1.71 (1.40-2.14)	0.38	1.89	1.49 (1.66-1.71)	0.34	1.70	3	0.64	1.7

Histograms were shown each projection in comparison between before and after the training program in mean ESD, third quartile and DRLs (IAEA) as in Figure 4.1-4.7 and shown 7 selected projections in comparison between before and after the training program and DRLs (IAEA) as in Figure 4.8.

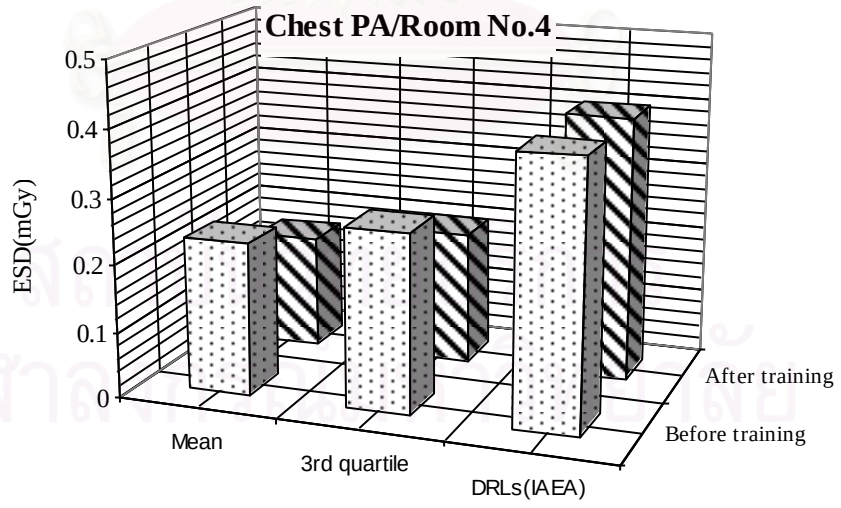

Figure 4.1 Histogram shown ESD of chest PA projection in mean, third quartile and DRLs of before and after the training program from Room No.4

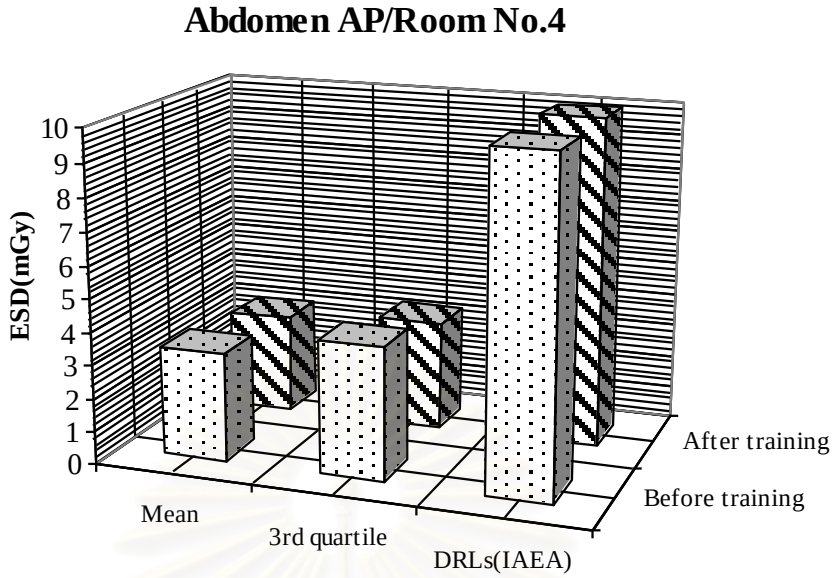

Figure 4.2 Histogram shown ESD of abdomen AP projection in mean, third quartile and DRLs of before and after the training program from Room No.4

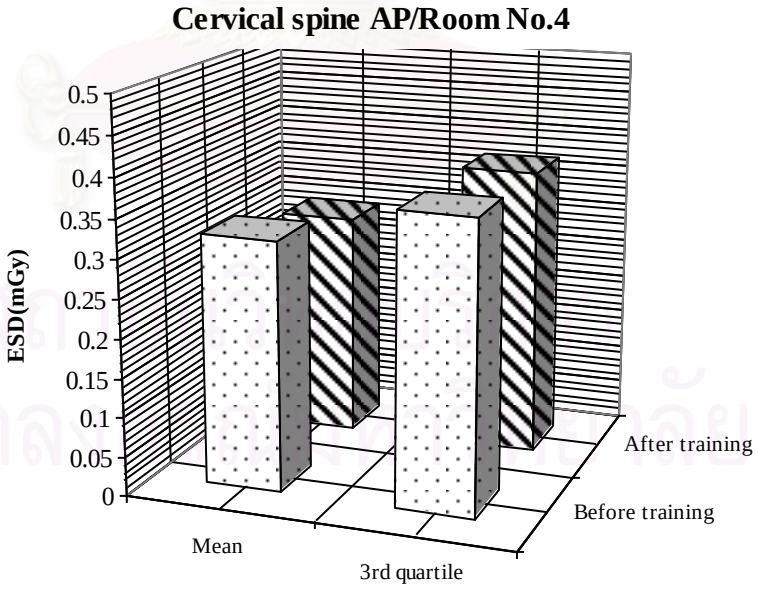

Figure 4.3 Histogram shown ESD of cervical spine AP projection in mean and third quartile of before and after the training program from Room No.4

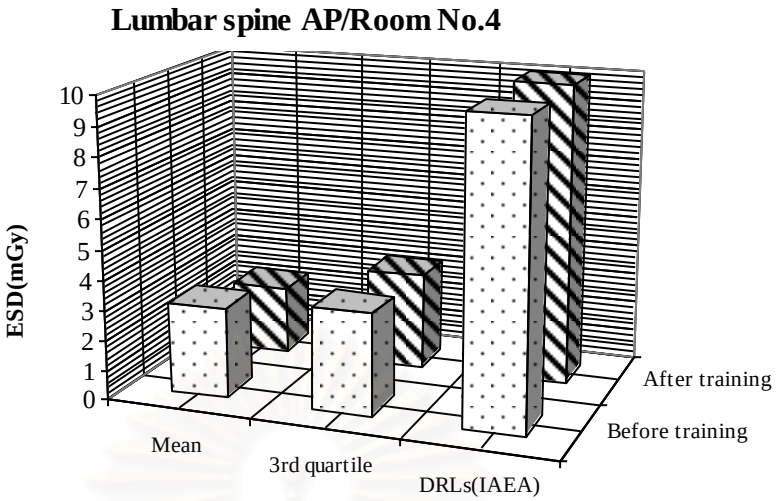

Figure 4.4 Histogram shown ESD of lumbar spine AP projection in mean, third quartile and DRLs of before and after the training program from Room No.4

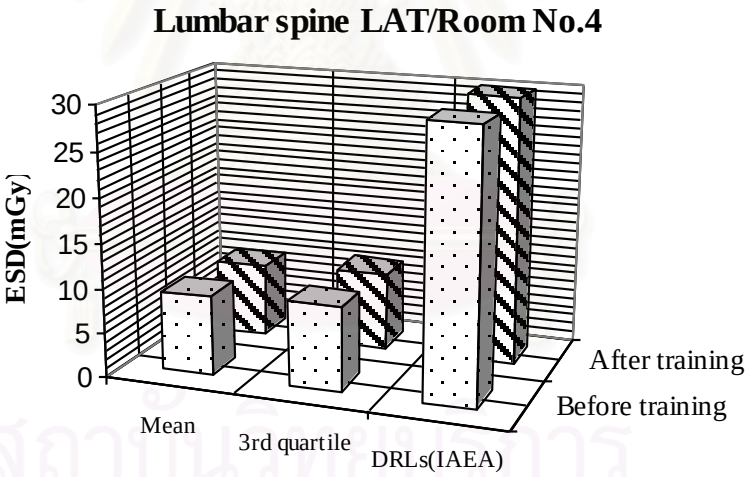

Figure 4.5 Histogram shown ESD of lumbar spine LAT projection in mean, third quartile and DRLs of before and after the training program from Room No.4

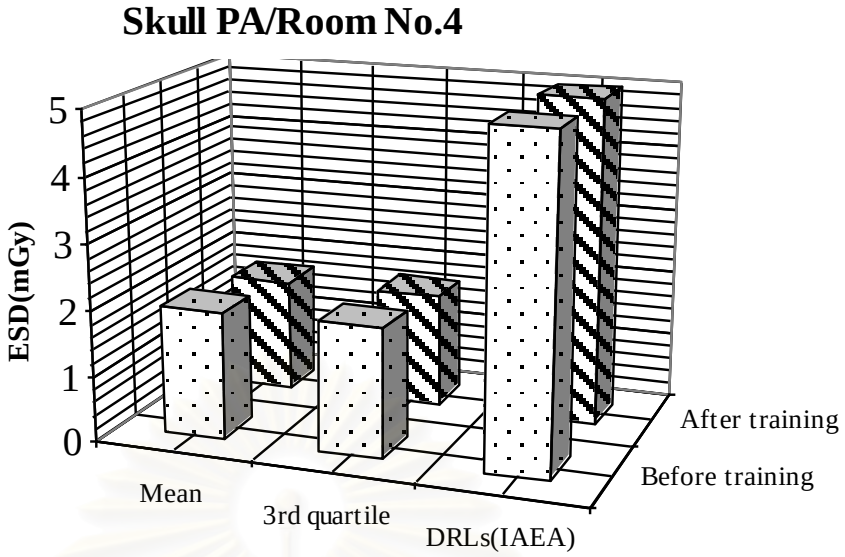

Figure 4.6 Histogram shown ESD of skull PA projection in mean, third quartile and DRLs of before and after the training program from Room No.4

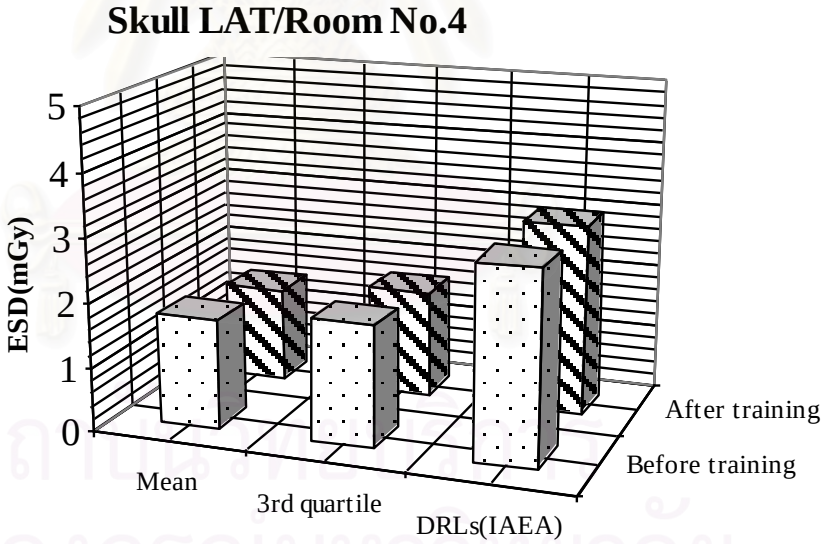

Figure 4.7 Histogram shown ESD of skull LAT projection in mean, third quartile and DRLs of before and after the training program from Room No.4

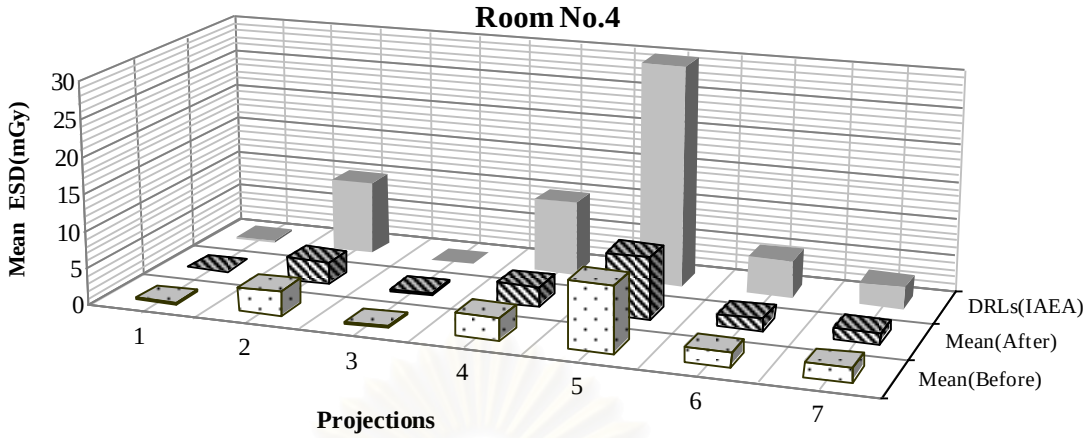

Figure 4.8 Histogram shown mean ESD (mGy) from *Room No.4* of 7 selected projections, 1 represents chest PA, 2 represents abdomen AP, 3 represents cervical spine AP, 4 represents lumbar spine AP, 5 represents lumbar spine LAT, 6 represents skull PA and 7 represents skull LAT compared among before, after training and DRLs(IAEA)

Table 4.39, chest PA from Room EMS, before the training program, the mean ESD (mGy) and range in parenthesis was 0.36(0.22-0.40), SD was 0.05, third quartile was 0.40, after the training program the mean ESD (mGy) and range in parenthesis was 0.25(0.15-0.40), SD was 0.06, third quartile was 0.28, DRLs (IAEA) was 0.4, P-value was 0.00 and percent of dose reduction was 30.5.

Abdomen AP from Room EMS, before the training program, the mean ESD (mGy) and range in parenthesis was 2.84(2.06-3.99), SD was 0.57, third quartile was 3.20, after the training program the mean ESD (mGy) and range in parenthesis was 2.81(1.92-4.24), SD was 0.56, third quartile was 3.20, DRLs (IAEA) was 10, P-value was 0.74 and percent of dose reduction was 2.5.

Cervical spine AP from Room EMS, before the training program, the mean ESD (mGy) and range in parenthesis was 0.34(0.23-0.38), SD was 0.04, third quartile was 0.37, after the training program the mean ESD (mGy) and range in parenthesis was 0.33(0.29-0.34), SD was 0.02, third quartile was 0.34, DRLs (IAEA) was not reported, P-value was 0.00 and percent of dose reduction was 2.9.

Lumbar spine AP from Room EMS, before the training program, the mean ESD (mGy) and range in parenthesis was 2.20(1.01-3.54), SD was 0.73, third quartile was 2.59, after the training program the mean ESD (mGy) and range in parenthesis was 1.96(0.71-3.03), SD was 0.81, third quartile was 2.41, DRLs (IAEA) was 10, P-value was 0.03 and percent of dose reduction was 10.

Lumbar spine LAT from Room EMS, before the training program, the mean ESD (mGy) and range in parenthesis was 8.79(7.33-10.85), SD was 1.08, third quartile was 9.74, after the training program the mean ESD (mGy) and range in parenthesis was 7.90(6.42-10.37), SD was 1.26 third quartile was 8.88, DRLs(IAEA) was 30, P-value was 0.00 and percent of dose reduction was 10.1.

Skull PA from Room EMS, before the training program, the mean ESD (mGy) and range in parenthesis was 1.57(1.42-1.82), SD was 0.22, third quartile was 1.65,

after the training program the mean ESD (mGy) and range in parenthesis was 1.26(1.24-1.29), SD was 0.03, third quartile was 1.27, DRLs (IAEA) was 5, P-value was 0.11 and percent of dose reduction was 19.7.

Skull LAT from Room EMS, before the training program, the mean ESD (mGy) and range in parenthesis was 1.58(1.33-1.82), SD was 0.35, third quartile was 1.70, after the training program the mean ESD (mGy) and range in parenthesis was 1.20(1.09-1.13), SD was 0.14, third quartile was 1.12, DRLs (IAEA) was 3, P-value was 0.24 and percent of dose reduction was 29.7.

Table 4.39 Entrance skin dose, ESD(mGy), are shown in mean and range in parenthesis, SD and third quartile in comparison between before and after the training program of the same examination room (*Room EMS*), and DRLs(IAEA), P-value and percent of dose reduction

Projections :EMS room	Entrance Skin Dose, ESD (mGy)						DRLs (IAEA)	P-value	% dose reduction
	Before Training			After Training					
	Mean (min-max)	SD	3rd quartile	Mean (min-max)	SD	3rd quartile			
Chest PA	0.36 (0.22-0.40)	0.05	0.40	0.25 (0.15-0.40)	0.06	0.28	0.4	0.00	30.5
Abdomen AP	2.84 (2.06-3.99)	0.57	3.20	2.81 (1.92-4.24)	0.56	3.20	10	0.74	2.5
Cervical spine AP	0.34 (0.23-0.38)	0.04	0.37	0.33 (0.29-0.34)	0.02	0.34	-	0.00	2.9
Lumbar spine AP	2.20 (1.01-3.54)	0.73	2.59	1.96 (0.71-3.03)	0.81	2.41	10	0.03	10
LAT	8.79 (7.33-10.85)	1.08	9.74	7.90 (6.42-10.37)	1.26	8.88	30	0.00	10.1
Skull PA	1.57 (1.42-1.82)	0.22	1.65	1.26 (1.24-1.29)	0.03	1.27	5	0.11	19.7
LAT	1.58 (1.33-1.82)	0.35	1.70	1.20 (1.09-1.13)	0.14	1.12	3	0.24	29.7

Histograms were shown each projection in comparison between before and after the training program in mean ESD, third quartile and DRLs (IAEA) as in Figure 4.9-4.15 and shown 7 selected projections in comparison between before and after the training program and DRLs (IAEA) as in Figure 4.16.

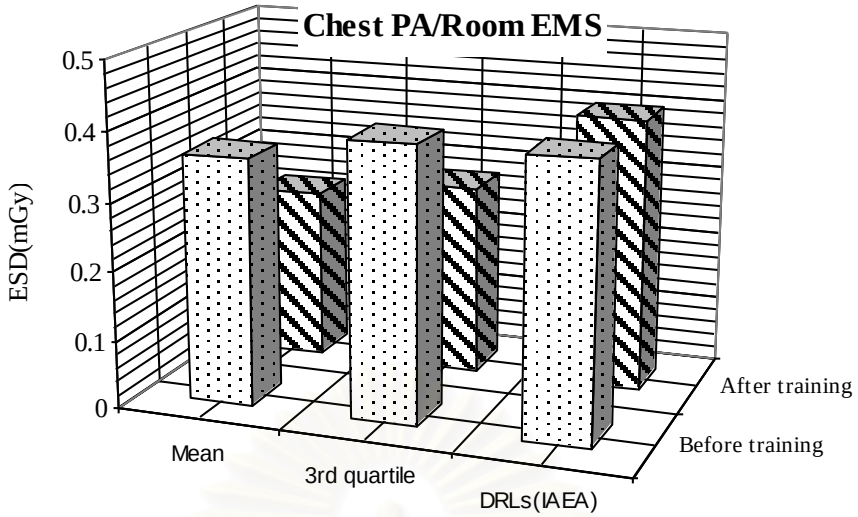

Figure 4.9 Histogram shown ESD of chest PA projection in mean, third quartile and DRLs of before and after the training program from Room EMS

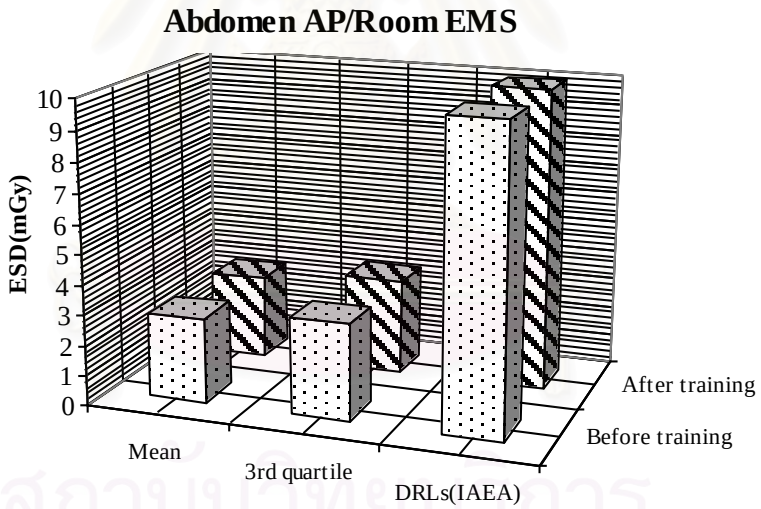

Figure 4.10 Histogram shown ESD of abdomen AP projection in mean, third quartile and DRLs of before and after the training program from Room EMS

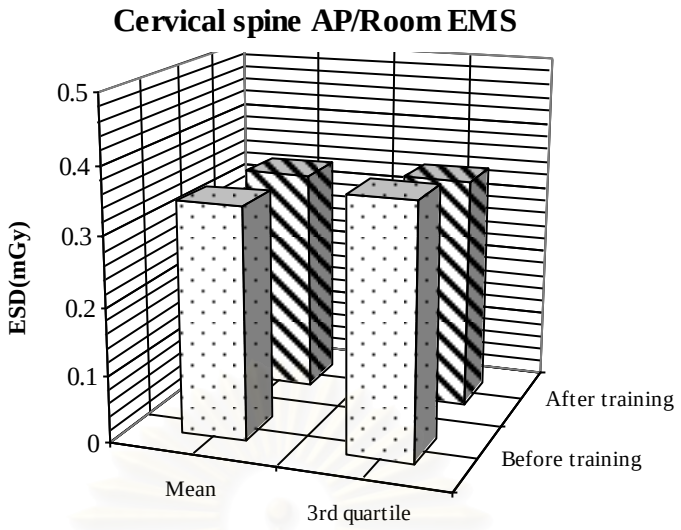

Figure 4.11 Histogram shown ESD of cervical spine AP projection in mean and third quartile of before and after the training program from Room EMS

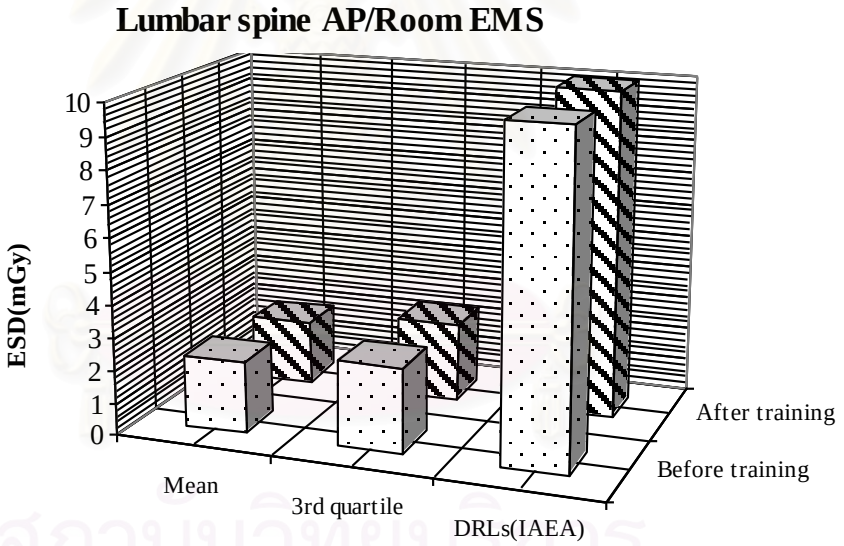

Figure 4.12 Histogram shown ESD of lumbar spine AP projection in mean, third quartile and DRLs of before and after the training program from Room EMS

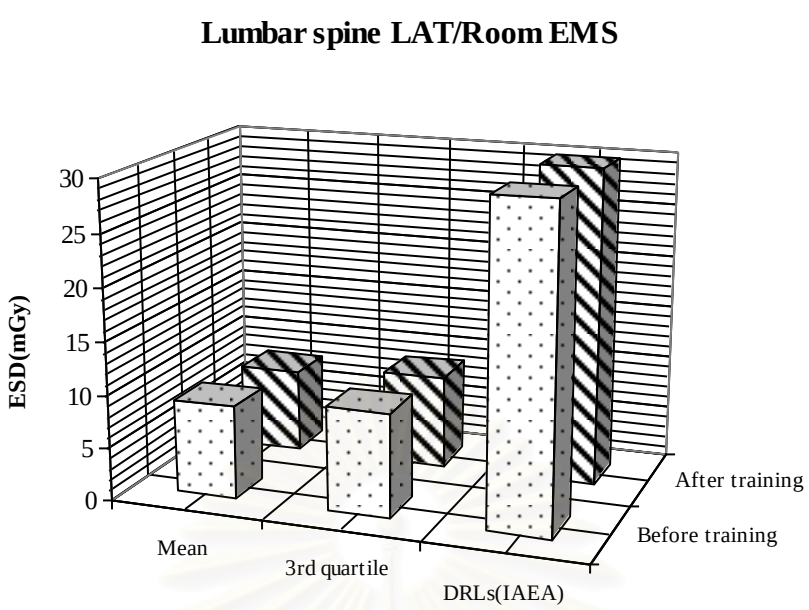

Figure 4.13 Histogram shown ESD of lumbar spine LAT projection in mean, third quartile and DRLs of before and after the training program from Room EMS

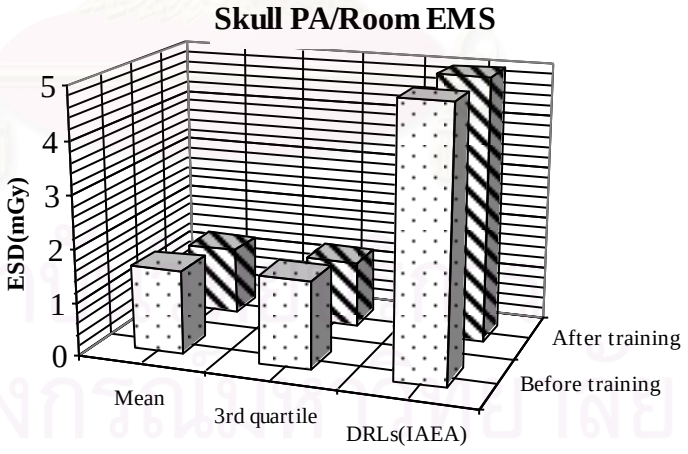

Figure 4.14 Histogram shown ESD of skull PA projection in mean, third quartile and DRLs of before and after the training program from Room EMS

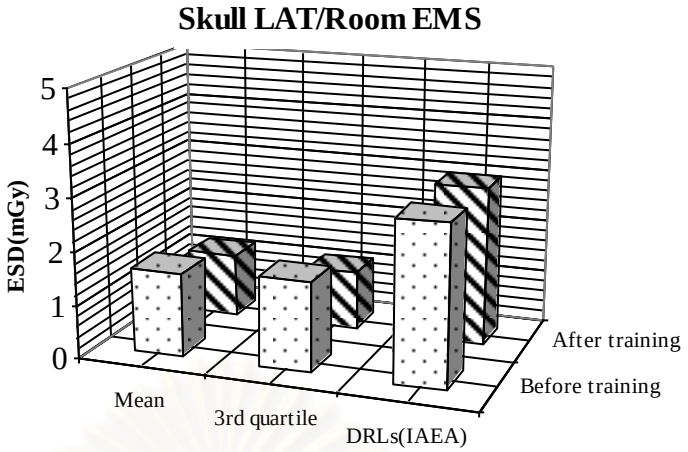

Figure 4.15 Histogram shown ESD of skull LAT projection in mean, third quartile and DRLs of before and after the training program from Room EMS

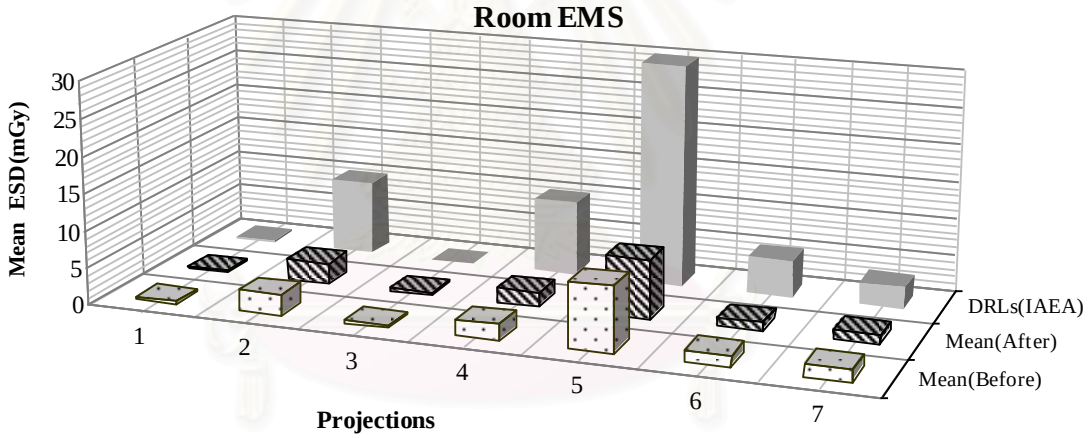

Figure 4.16 Histogram shown mean ESD (mGy) from *Room EMS* of 7 selected projections, 1 represents chest PA, 2 represents abdomen AP, 3 represents cervical spine AP, 4 represents lumbar spine AP, 5 represents lumbar spine LAT, 6 represents skull PA and 7 represents skull LAT compared among before, after training and DRLs(IAEA)

Mean effective dose to adult patients was calculated by using the conversion coefficients of Hart et al.[32] in comparison between before and after the training program in both rooms, No.4 and EMS, as shown in Table 4.40.

Mean effective dose for chest PA from Room No.4, before and after the training program in μSv, was 23 and 17, abdomen AP was 467.6 and 424.2, cervical spine AP was 32 and 29, lumbar spine AP was 323.1 and 291, lumbar spine LAT was 223.3 and 208 and skull PA was 19.3 and 17.4.

Mean effective dose for chest PA from Room EMS, before and after the training program in μSv, was 36 and 25, abdomen AP was 397.6 and 393.4, cervical spine AP was 34 and 33, lumbar spine AP was 235.4 and 209.7, lumbar spine LAT was 219.8 and 197.5 and skull PA was 15.7 and 12.6

Table 4.40 Mean effective dose are shown in comparison between before and after the training program from *Room No.4* and *Room EMS*

Projections	Mean effective dose μSv			
	Room No.4		Room EMS	
	Before	After	Before	After
Chest PA	23	17	36	25
Abdomen AP	467.6	424.2	397.6	393.4
Cervical spine AP	32	29	34	33
Lumbar spine AP	323.1	291	235.4	209.7
LAT	223.3	208	219.8	197.5
Skull PA	19.3	17.4	15.7	12.6

To compare mean patient entrance skin dose in common diagnostic radiographic examinations after the training on both rooms, Room No.4 and Room EMS, in this study and similar x-ray examinations in various countries is shown in Table 4.41

Table 4.41 Comparison of mean entrance skin dose to patients in common diagnostic radiographic examinations on both rooms, Room No.4 and Room EMS, in this study and from similar x-ray examinations in various countries (*Without BSF)

Countries	Mean ESD(mGy)				
	Chest PA	Abdomen AP	Lumbar spine AP	Lumbar spine LAT	Skull AP/PA
USA	0.25*	4.5*	5*	-	-
UK	0.15	4.7	5	11.7	2.3
Australia	0.12	4.2	6.1	15.1	1.9
Canada	0.11	2.35	3.34	-	-
Finland	0.24	7.1	8.8	18.2	3.4
Greece	0.18	1.36	-	-	-
Korea	0.21	2.33	2.8	6.17	2.04
Taiwan	0.52	4.77	5.91	18.9	2.6
New Zealand	0.22	20.4	22.8	35.5	3
This study:					
Room No.4	**0.17**	**3.03**	**2.72**	**8.32**	**1.74**
Room EMS	**0.25**	**2.81**	**1.96**	**7.90**	**1.26**

4.5.2 Comparison image quality between before and after the training program

Comparison in number of A, B and C grade image, A-grade was collected from Room No.4 and Room EMS and compared into before and after the training program. For chest PA, from Room No.4, number of A-grade image in before and after the training was 28 and 31. For abdomen AP, from Room No.4, number of A-grade image

in before and after the training was 14 and 18. For cervical spine AP, from Room No.4, number of A-grade image in before and after the training was 1 and 7. For lumbar spine AP, from Room No.4, number of A-grade image in before and after the training was 10 and 15. For lumbar spine LAT, from Room No.4, number of A-grade image in before and after the training was 3 and 19. For skull PA, from Room No.4, number of A-grade image in before and after the training was 2 and 3. For skull LAT, from Room No.4, number of A-grade image in before and after the training was 2 and 2. The total of A-grade image from Room No.4 was 70 and 95, and percent of image improve was 35.7

For chest PA, from Room EMS, number of A-grade image in before and after the training was 31 and 36. For abdomen AP, from Room EMS, number of A-grade image in before and after the training was 23 and 31. For cervical spine AP, from Room EMS number of A-grade image in before and after the training was 2 and 7. For lumbar spine AP, from Room EMS, number of A-grade image in before and after the training was 13 and 16. For lumbar spine LAT, from Room EMS, number of A-grade image in before and after the training was 14 and 15. For skull PA, from Room EMS, number of A-grade image in before and after the training was 1 and 3. For skull LAT, from Room EMS, number of A-grade image in before and after the training was 1 and 2. The total of A-grade image from Room EMS in before and after the training was 85 and 110, and percent of image improve was 29.4, as shown in Table 4.42

Table 4.42 The number of A-grade images from selected projections in image quality between before and after the training program, from *Room No.4* and *Room EMS*. The total of A-grade image in both rooms and percent of image improve

Projections	A grade image			
	Room No.4		Room EMS	
	Before	After	Before	After
Chest PA	28	31	31	36
Abdomen AP	14	18	23	31
Cervical spine AP	1	7	2	7
Lumbar spine AP	10	15	13	16
LAT	3	19	14	15
Skull PA	2	3	1	3
LAT	2	2	1	2
Total	70	95	85	110
Percent image improve	35.7		29.4	

Number of A-grade image from Room No.4 of chest PA, abdomen AP, cervical AP, lumbar AP, lumbar LAT, skull PA, and skull LAT in before and after the training program as shown in Figure 4.17 and from Room EMS in Figure 4.18

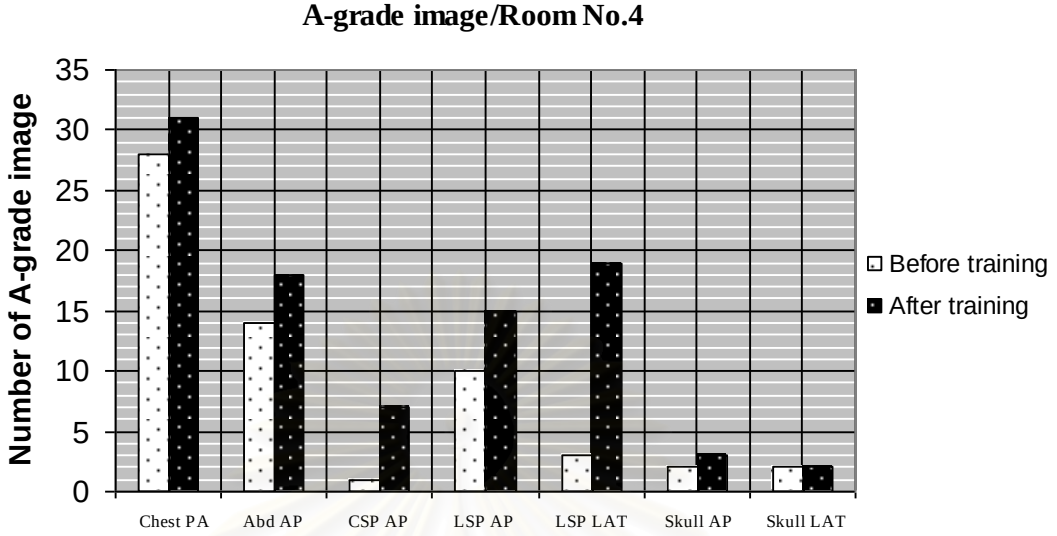

Figure 4.17 Number of A-grade image from Room No.4 of chest PA, abdomen AP, cervical AP, lumbar AP, lumbar LAT, skull PA, and skull LAT in before and after the training program

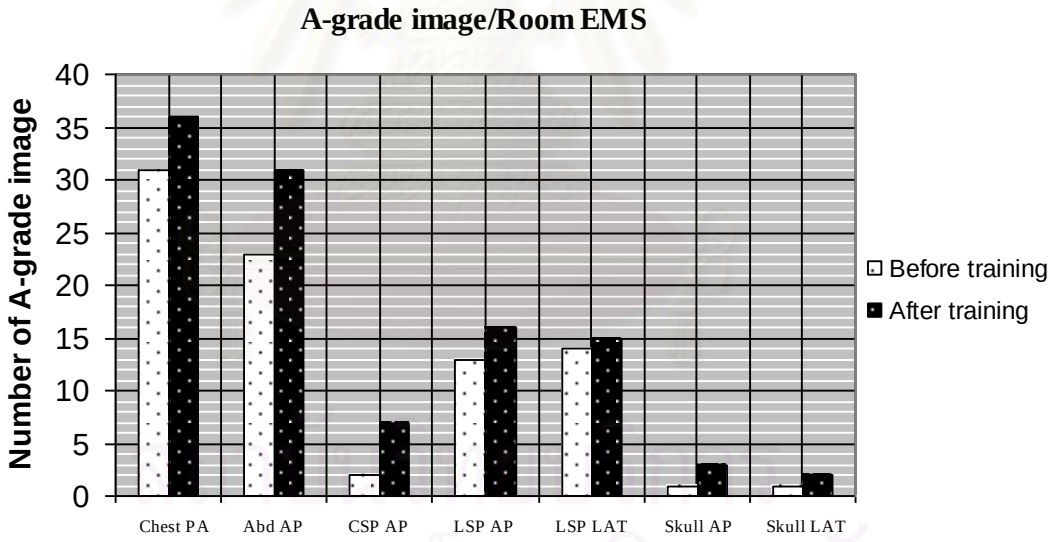

Figure 4.18 Number of A-grade image from Room EMS of chest PA, abdomen AP, cervical AP, lumbar AP, lumbar LAT, skull PA, and skull LAT in before and after the training program

The number of B-grade image were summarized and classified into positioning, over exposure, under exposure and artifact in before and after the training from Room No.4. For chest PA, number of B-grade image in positioning was 2 and 0, over exposure was 1 and 2, under exposure was 0 and 0 and artifact was 4 and 2. For abdomen AP, number of B-grade image in positioning was 4 and 5, over exposure was 2 and 0, under exposure was 0 and 0, and artifact was 3 and 0. For cervical spine AP, number of B-grade image in positioning was 0 and 2, over exposure was 0 and 0, under

exposure was 8 and 0, and artifact was 0 and 0. For lumbar spine AP, number of B-grade image in positioning was 0 and 0, over exposure was 0 and 0, under exposure was 3 and 0, and artifact was 2 and 0. For lumbar spine LAT, number of B-grade image in positioning was 3 and 1, over exposure was 0 and 0, under exposure was 3 and 0 and artifact was 1 and 0. For skull PA, number of B-grade image in positioning was 1 and 0, over exposure was 0 and 0, under exposure was 0 and 0, and artifact was 0 and 0. For skull LAT, number of B-grade image in positioning was 1 and 1, over exposure was 0 and 0, under exposure was 0 and 0 and artifact was 0 and 0, as shown in Table 4.43. Histograms were shown number of B-grade image and causes from Room No.4 in comparison between before and after the training program, as Figure 4.19.

Percent poor image quality improve after the training program from Room No.4 was 18.2 in positioning, 33.3 in over exposure, 100 in under exposure and 80 in artifact as shown in Table 4.43

Table 4.43 The number of B-grade images from selected projections in image quality between before and after the training program, from *Room No.4*, are classified into positioning, over exposure, under exposure and artifact, and percent of poor image quality improve

Room No.4	Positioning		Over exposure		Under exposure		Artifact	
	Before	After	Before	After	Before	After	Before	After
Chest PA	2	0	1	2	0	0	4	2
Abdomen AP	4	5	2	0	0	0	3	0
C-spine AP	0	2	0	0	8	0	0	0
L-spine AP	0	0	0	0	3	0	2	0
L-spine LAT	3	1	0	0	3	0	1	0
Skull PA	1	0	0	0	0	0	0	0
Skull LAT	1	1	0	0	0	0	0	0
Total	11	9	3	2	14	0	10	2
% poor image quality improve	18.2		33.3		100		80	

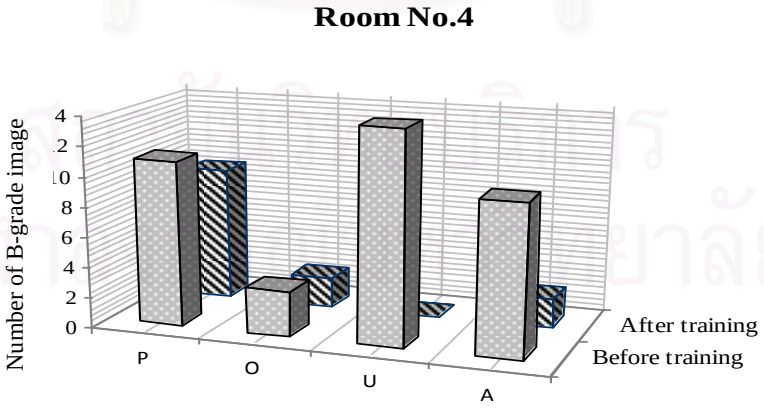

Figure 4.19 Histogram shown the number of B-grade images in image quality between before and after the training program which classified into positioning(P), over(O)-under(U) exposure and artifact (A) from Room No.4

The number of B-grade image were summarized and classified into positioning, over exposure, under exposure and artifact in before and after the training from Room EMS. For chest PA, number of B-grade image in positioning was 6 and 1, over exposure was 0 and 0, under exposure was 0 and 0 and artifact was 0 and 0. For abdomen AP, number of B-grade image in positioning was 6 and 3, over exposure was 0 and 0, under exposure was 0 and 1, and artifact was 6 and 0. For cervical spine AP, number of B-grade image in positioning was 0 and 1, over exposure was 0 and 0, under exposure was 7 and 1, and artifact was 0 and 0. For lumbar spine AP, number of B-grade image in positioning was 0 and 0, over exposure was 0 and 0, under exposure was 3 and 0, and artifact was 0 and 0. For lumbar spine LAT, number of B-grade image in positioning was 5 and 3, over exposure was 0 and 0, under exposure was 0 and 1 and artifact was 0 and 0. For skull PA, number of B-grade image in positioning was 2 and 0, over exposure was 0 and 0, under exposure was 0 and 0, and artifact was 0 and 0. For skull LAT, number of B-grade image in positioning was 1 and 0, over exposure was 0 and 0, under exposure was 0 and 0 and artifact was 0 and 0, as shown in Table 4.44. Histograms were shown number of B-grade image and causes from Room EMS in comparison between before and after the training program, as Figure 4.20.

Percent poor image quality improve after the training program from Room EMS was 65 in positioning, 0 in over exposure, 72.7 in under exposure and 100 in artifact shown in Table 4.44

C-grade image was not graded by two radiologists.

For this study, exposure technique followed image quality criteria which was European guidelines recommendations for diagnostic radiographic images (EUR 16260) as shown in Table 4.45

Table 4.44 The number of B-grade images from selected projections in image quality between before and after the training program, from *Room EMS*, are classified into positioning, over exposure, under exposure and artifact, and percent of poor image quality improve

Room EMS	Positioning		Over exposure		Under exposure		Artifact	
	Before	After	Before	After	Before	After	Before	After
Chest PA	6	1	0	0	0	0	0	0
Abdomen AP	6	3	0	0	0	1	6	0
C-spine AP	0	1	0	0	7	1	0	0
L-spine AP	0	0	0	0	3	0	0	0
L-spine LAT	5	3	0	0	0	1	0	0
Skull PA	2	0	0	0	0	0	0	0
Skull LAT	1	0	0	0	0	0	0	0
Total	20	7	0	0	10	3	6	0
% poor image quality improve	65		0		70		100	

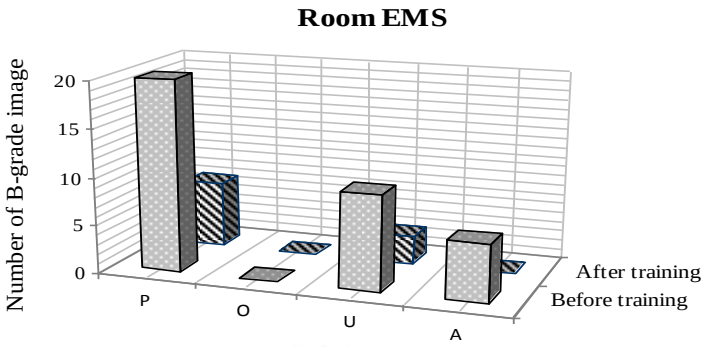

Figure 4.20 Histogram shown the number of B-grade images in image quality between before and after the training program which classified into positioning(P), over(O)-under(U) exposure and artifact (A) from Room EMS

Table 4.45 European guidelines on quality criteria recommendations for diagnostic radiographic images (EUR 16260)

Projections	kVp	FFD(cm)	Focal Spot(mm)	Exposure Time (mSec)	DRLs (mGy)
Chest PA	125	180 (140-200)	<1.3	<20	0.3
Chest LAT	125	180 (140-200)	<1.3	<40	1.5
Skull PA	70-85	115(100-150)	0.6	<100	5
Skull LAT	70-85	115(100-150)	0.6	<100	3
Lumbar spine AP	75-90	115(100-150)	<1.3	<100	30
Lumbar spine LAT	80-95	115(100-150)	<1.3	<100	40
Pelvic AP	75-90	115(100-150)	<1.3	<100	10

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Discussion

The radiation dose to patients and quality in X-ray examinations form an important component of a QC and training program, especially in the new technology such as the computed radiography system. Knowledge and understanding of patient dose level and the image quality, as well as reasons behind higher doses and poor quality, provide a basis for setting corrective actions in order to optimize the protection of the patient in an effective manner. Patients (and their relatives) expect to be informed about clinical risks including radiation risks, hence another aspect of the usefulness of patient dose data. Information on patient doses and image quality is better known in some developed countries, where QC and training programs have already been set up the number of national surveys performed. Similar information is grossly lacking in the majority of the developing countries where efforts to establish QC and training programs were initiated by the IAEA. Therefore the information obtained in the present survey of practice of conventional and computed radiography practices is aimed at assessing the initial situation in terms of differences in practices and potentials for optimization, such that it can be used to contribute to establishment of QC and training programs.

The patients ESD from 458 patients were divided into before and after the training, 229 patients per each period. The 229 patient data were separated into two rooms Room No.4 and Room EMS.

For both rooms, the mean ESD of selected projections and variations have been determined. In this study the variations are small probably because the dose range is narrow. Mean ESD after the training program was not greater than before training program and percent dose of all projections were reduced.

For Room No.4, there was no statistically significant improvement in patient dose after training for abdomen AP, cervical spine AP, lumbar spine AP, lumbar spine LAT, skull PA and skull LAT examinations ($p>0.05$), whereas the chest PA has statistically significant improved ($p<0.05$). The patient dose from chest PA after training was lower than the dose before training in 30% dose reduction this was due to the lower in mean mAs used after training.

For Room EMS, there was no statistically significant improvement in patient dose after training for abdomen AP, lumbar spine AP, skull PA and skull LAT examinations ($p>0.05$), whereas for chest PA, cervical spine AP and lumbar spine LAT were statistically significant improved ($p<0.05$). The patient dose from chest PA and cervical spine AP after training was lower than the dose before training. These were due to the lower in mean kVp used after training whereas the patient dose from lumbar spine LAT was lower than the dose before training. This was due to the lower in mean mAs used after training. Statistic analysis in term of mean ESD showed that kVp and mAs were the good indication that they are the determining factor in resultant patient dose.

The mean ESD from both rooms of all projections after training were less than before training, as to many reasons. Firstly data were collected by the same radiological technologists for before and after the training. Secondary, the ESD was compared room

by room as the same period of before and after the training and thirdly, the exposure charts have been posted in both rooms. All of these reasons result in dose reduction and diagnostically acceptable image quality.

The image quality assessment demonstrated a high frequency of poor quality radiographs (grade B) in the period of before training. Two radiologists scored all images of the same score in A and B-grade image from both rooms, and also the same of B-grade image causes. For the C-grade image, there was no score. The poor of image causes quality improved from all causes after the training program, positioning, over-under exposure and artifact as shown in Table 4.43 from Room No.4 and Table 4.44 from Room EMS. High percentage of poor image quality is likely to be due to many reasons, such as radiological technique, inexperience of radiological technologists and technical problems. Because of the advantage in large dynamic range of CR system, it is easy to expose patients with higher kVp and mAs without awareness of darker image. The radiological technologists developed a tendency to use higher kVp and mAs than necessary to get good image quality and avoid the retake by post processing technique. There is a preference by radiologists and radiological technologists for overexposure rather than the grainy, noisy appearance of underexposure images. An experienced radiological technologist would lower patient positioning time and minimum poor radiograph. Technical problem are directly to the radiological equipments that should be available during patient examination. This study showed that poor image quality after the training program are improved, this is supported by the results of the second phase (after training) on image quality assessment, in terms of increasing in the percentage of grade A images from both rooms at the second phase. The result shows a strong indication that radiological technologists must be the ones who participated in the training program in order to minimize poor image quality.

Patient information such as body part thickness, exposure parameter, output of the x-ray machine and manufacturer's guideline of each CR system are to be concerned when dealing with the patient dose and image quality. Increasing in body part thickness resulted in mean ESAK and mean ESD increasing. Differences in patient body habitués, which would affect the exposure required. The obese patients have a chance to receive higher radiation dose than the thin one. For exposure techniques, increasing in kVp and mAs resulted in increasing ESD. The kVp and FFD applied in this study were within European guidelines recommendations for diagnostic radiographic images (EUR 16260) and also DRLs as shown in Table 4.45. For chest examination high kVp technique (120-125 kVp)had been selected in both periods, before and after the training, resulted in mean ESD after the training is less than before training and within DRLs with image acceptable. However, for decreasing focal skin distance (FSD) resulted in increasing ESD because of the inverse square law and the image would be enlarged with degradation in image quality.

Determination of patient doses or ESD values and their comparison with DRLs is an important part of the optimization process in diagnostic radiology. A comparison of average dose levels from a specified imaging procedure with DRLs should identify unusually high or low doses for the particular procedure. This survey has shown that most ESD values were well below the DRLs recommended by the IAEA. Except for a few cases in chest PA, from before and after the training, the dose values obtained were equal the DRLs (IAEA). For mean ESD values of all projections were below the DRLs, as shown in Table 4.38 and Table 4.39. Comparison of cervical spine is not possible as

there are no available reference dose values. However, experience elsewhere has shown that there is little correlation between patient dose and image quality and as such the ESD results cannot be directly related to the image quality status discussed earlier. Comparison of ESD values under this study and others, Table 4.41, have largely shown comparable doses. Therefore the common assumption or feeling that radiation doses to patients in developing countries are always higher than those in developed countries is not correct. This study for example, mean ESD of chest PA from Room No.4 is lower than USA, Finland, Korea, Taiwan and New Zealand, Room EMS showed lower chest ESD than Taiwan. Some country, such as Canada, shows mean ESD of some projection (chest PA) lower than mean ESD of other countries, the reasons for this could be due to the use of digital radiograph, AEC and the use of CR system is established in Canada long before this study.

The effective dose estimates have re-confirmed that radiation risk to patients in conventional radiography, computed radiograph (CR) in this study, is smaller in comparison to that in other X-ray imaging modalities such as computed tomography (CT) or interventional procedures as shown in Table 5.1. Mean effective dose of CT chest (8 mSv) is approximately 400 times greater than CR of chest (0.02 mSv from Room No.4 and 0.03 mSv from Room EMS by the period after the training) which is the same type of examination. Despite this situation, the observed dose variations could mean unjustified risk to patients undergoing similar types of X-ray examinations. The potential for dose reduction without affecting the quality of radiographic images in this study has also been noted. This clearly indicates the positive QC and training program implementation and the adherence to general principles associated with good imaging performance. It is understood that the central requirement to these principles of good imaging is the proper functioning of radiology staff and not only equipment testing, QC checks as commonly perceived but also the training program in order to keep doses as low as reasonably achievable, ALARA, in CR system.

Table 5.1 Mean effective dose are shown in comparison between before and after the training program from Room No.4 and Room EMS to compare with the other modality such as computed tomography (CT)

Projections	Mean effective dose (mSv)				
	Computed Radiograph (this study)				*CT
	Room No.4		Room EMS		
	Before	After	Before	After	
Chest PA	0.02	0.02	0.04	0.03	8
Abdomen AP	0.47	0.42	0.40	0.39	10-20
Cervical spine AP	0.03	0.03	0.03	0.03	-
Lumbar spine AP	0.32	0.29	0.24	0.21	-
LAT	0.22	0.21	0.22	0.20	-
Skull PA	0.02	0.02	0.02	0.01	2

* ICRP publication 87

5.2 Conclusion

The study of image quality and patient dose levels in this hospital has been presented. Due to the signification findings of this study an importance of reducing patient dose, it is recommended that further radiological technologists education and training should be implemented. Initial training should include general education about CR, explanation of exposure technique and how they related to patient dose. In addition, regular quality assurance programs should be set up to record and monitor changes in exposure technique over time in order to control any exposure variation. It has been seen that variations in patient dose can be large to the extent of attracting suspicion as to necessity of such dose levels (if too high) or the status of image quality (if too low). Nevertheless, the magnitudes of patient doses are not higher than doses in developed countries.

The usefulness of the application of DRLs has been demonstrated, along with the potential for some dose reductions without adversely affecting the image quality. The experience from this study should then form a basis to strengthen QC and training programs where they exist and establish such programs where they do not yet exist. Such QC and training programs are necessary to ensure that appropriate radiation exposure is delivered to the image receptor to produce an image quality that is adequate for the diagnostic task. The potential for increased awareness of such a need for optimization is one of the positive impacts of this study in reducing unnecessary patient doses without compromising the image.

5.3 Recommendations

Introduction of a new imaging system on any center, with CR systems, an over-under exposure can occur without an adverse impact on image quality and could avoid unnecessary patient dose. Once CR systems are in use and the result on image quality and patient dose not go along with the expectation, it should follow these recommendations:

1. Radiological technologists must be the same ones who attend the training program in order to expose patient in the period before and after the training and dose comparison must be set at the same x-ray room in the period before and after the training.

2. In some situation that patient dose would not reduce within local DRLs and image quality would not improves, setting up appropriate training program monthly until the image quality improves.

3. Performs weekly image reviews and document the problem and share it with the appropriate staff member.

4. After the training program, the result of patient dose and image quality should be fed-back to the radiological technologists so that they can become aware of the dose data and how they compare to others.

5. Create exposure charts for patients of various sizes for a standard procedure in all x-ray rooms on a yearly basis, as well as comparison of the results with the DRLs. If

DRLs are consistently exceeded, appropriate corrective action and investigation of the causes are required to reduce doses while maintaining suitable image quality.

6. Continuing training should be conducted in parallel between new post-processing software an optimization program.

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APPENDICES

APPENDIX A

REPORT OF RADIOGRAPHIC SYSTEM PERFORMANCE

General Information

Location: Rajavithi Hospital
Date: Mar 20, 2008
Room number: Emergency Medical Service (EMS)
Manufacturer: BENNETT, USA (Tube unit; collimator filter 2.0mm.Al)
Model number: B-OTC
Serial number: B-00397

Checklist

P	General mechanical and electrical conditions
P	Tube angle indicator, tube motion and locks
P	Focus to film distance indicator (SID)
P	Field size indicator
P	Congruency of light and radiation fields
P	Crosshair centering
P	Focal spot size
P	Photo cell consistency
N/P	Bucky/Grid Centering
N/A	Automatic Collimation (PBL)
P	Beam Quality (Half Value Layer)
P	Consistency of exposure (mR/mAs)
P	kVp Accuracy
P	Timer accuracy
P	mA Linearity

P = Performed
N/P = Not Performed
N/A = Not Applicable

Beam Quality (Half Value Layer)

Method: set 80 kVp.
Requirement: NCRP #33 recommends not less than 2.3 mm. Al at 80 kVp.

Set kVp: 80 **Measure kVp :** 80.62

Filter (mm.Al)	Instrument Reading (mR)
Open	239.1
1	195.4
2	164.7
3	139
3.5	128.8
4	120.7

Calculated HVL: 3.47 mm. Al

mA or mAs Linearity

Method: select 80 kVp and time close to 0.100 ms and cycle through all mA stations and record the exposure in mR (Requirement: coefficient of variation should not exceed 0.1.)

S/L	Avg. kVp	mA	Time	mAs	mR	mR/mAs	C.V.
L	80.89	200	0.025	5.0	46.2	9.240	-0.008
	80.89	200	0.05	10.0	93.87	9.387	-0.005
	80.63	200	0.075	15.0	142.2	9.480	0.004
	80.82	200	0.1	20.0	188.2	9.410	-0.006
	81.04	200	0.125	25.0	237.9	9.516	0.002
	80.96	200	0.15	30.0	284.4	9.480	-0.027
S	81.13	150	0.03	4.9	42.59	8.692	0.002
	81.15	150	0.07	10.1	87.43	8.656	0.006
	81.14	150	0.1	15.0	128.4	8.560	0.000
	81.70	150	0.13	19.9	170.5	8.568	-0.005
	81.76	150	0.17	25.1	217.2	8.653	0.003
	81.46	150	0.2	30.0	257.8	8.593	

Mean (L): 9.419 Std. Dev. (L): 0.1 C.V. (L): 0.011
Mean (S): 8.620 Std. Dev. (S): 0.05 C.V. (S): 0.006

kVp Linearity and Consistency of Exposure

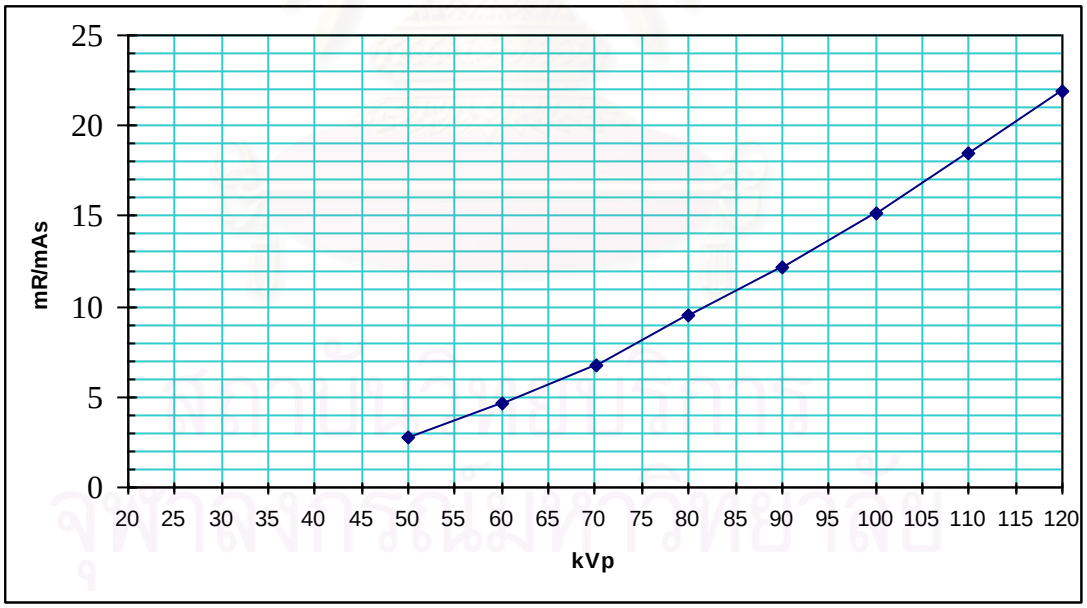
Method: at a mid-current (25 mAs) station, vary the kVp from minimum to maximum in steps of 10 kVp. Record the average kVp and exposure, mR then calculate mR/mAs. Plot curve between kVp and mR/mAs

Requirement: the deviation should not exceed 5 kVp or 10% of set kVp, whichever is larger.

Set SCD: 26” **Phase** 3

mA: 200L **Time:** 0.125 **sec** **mAs:** 25

Set kVp	Avg.	% Dev.	mR	mR/mAs
50	50.38	0.76%	69.27	2.77
60	60.98	1.63%	115.10	4.60
70	70.33	0.47%	168.90	6.76
80	80.53	0.66%	236.60	9.46
90	90.26	0.29%	303.00	12.12
100	100.80	0.80%	379.00	15.16
110	111.00	0.91%	462.30	18.49
120	121.80	1.50%	547.20	21.89



General Information

Location: Rajavithi Hospital
Date: Mar 19, 2008
Room number: 4
Manufacturer: Trex, USA (Tube unit; collimator filter 2.0 mm. Al)
Model number: MC-150
Serial number: FH33159

Checklist

P	General mechanical and electrical conditions
P	Tube angle indicator, tube motion and locks
P	Focus to film distance indicator (SID)
P	Field size indicator
P	Congruency of light and radiation fields
P	Crosshair centering
P	Focal spot size
P	Photo cell consistency
N/P	Bucky/Grid Centering
N/A	Automatic Collimation (PBL)
P	Beam Quality (Half Value Layer)
P	Consistency of exposure (mR/mAs)
P	kVp Accuracy
P	Timer accuracy
P	mA Linearity

P = Performed
N/P = Not Performed
N/A = Not Applicable

Beam Quality (Half Value Layer)

Method: set 80 kVp.
Requirement: NCRP #33 recommends not less than 2.3 mm. Al at 80 kVp.

Set kVp: 80 **Measure kVp :** 77.94

Filter (mm.Al)	Instrument Reading (mR)
Open	265
1	210.9
2	174
3	145
3.5	132.4
4	122.9

Calculated HVL: 3.12 mm. Al

mA or mAs Linearity

Method: select 80 kVp and time close to 0.100 ms and cycle through all mA stations and record the exposure in mR (Requirement: coefficient of variation should not exceed 0.1.)

S/L	Avg. kVp	mA	Time	mAs	mR	mR/mAs	C.V.
L	78.61	200	0.03	5.0	54.4	10.880	0.018
	78.06	200	0.05	10.0	105	10.500	-0.006
	78.50	200	0.08	15.0	159.3	10.620	0.003
	78.51	200	0.10	20.0	211.1	10.555	-0.005
	78.35	200	0.13	25.0	266.7	10.668	0.002
	78.24	200	0.15	30.0	318.6	10.620	-0.014
S	78.59	150	0.04	4.9	48.85	9.969	-0.001
	78.23	150	0.07	10.1	100.9	9.990	0.011
	78.23	150	0.10	15.0	146.6	9.773	0.003
	78.49	150	0.14	19.9	193.2	9.709	0.005
	78.58	150	0.17	25.1	241.2	9.610	0.003
	78.55	150	0.20	30.0	286.5	9.550	

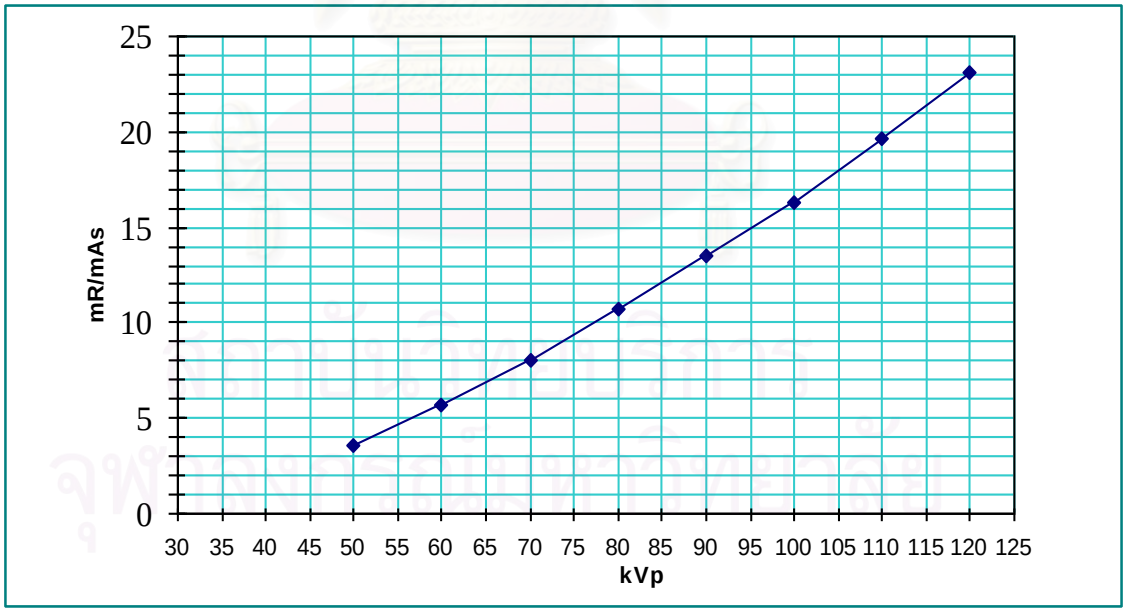
Mean (L): 10.64 **Std. Dev. (L): 0.131** **C.V. (L): 0.012**
Mean (S): 9.767 **Std. Dev. (S): 0.182** **C.V. (S): 0.019**

kVp Linearity and Consistency of Exposure

Method: at a mid-current (25 mAs) station, vary the kVp from minimum to maximum in steps of 10 kVp. Record the average kVp and exposure, mR then calculate mR/mAs. Plot curve between kVp and mR/mAs
Requirement: the deviation should not exceed 5 kVp or 10% of set kVp, whichever is larger.

Set SCD: 26” **Phase** 3
mA: 200L **Time:** 0.125 **sec** **mAs:** 25

Set kVp	Avg.	% Dev.	mR	mR/mAs
50	49.17	1.66%	89.43	3.58
60	59.18	1.37%	143.60	5.74
70	68.57	2.04%	200.20	8.01
80	78.37	2.04%	266.70	10.67
90	88.05	2.17%	338.30	13.53
100	98.33	1.67%	408.30	16.33
110	108.90	1.00%	491.60	19.66
120	118.80	1.00%	576.60	23.06



CR System Calibration

Result	System Test	Tolerance- The Established Criteria
P	**Monitor& Laser printer set-up**	The 5% on 0% and 95% on 100% details should be clearly visible. The horizontal and vertical resolutions should not differ by greater than 20%
P	**Dark Noise**	A uniform artifact free image should be expressed. The results in series of bands appearing across the image.
P	**Erasure cycle efficiency**	Absence of a ghost image of the lead block from the first exposure in the re-exposure image. There should be <1% (remedial) difference between the pixel values in the ghosted region and the surrounding areas. A suspension level of <5% is set.
P	**Sensitivity Index calibration**	The indicated exposure should agree with the measured exposure within 20%.
P	**Sensitivity Index consistency**	The variation in the calculated indicated exposure should not differ by greater than 20% between plates. The measurements repeated on the same plate should be used to lay down a baseline for future QA tests.
P	**Uniformity**	The images should not have obvious artifacts. If measuring uniformity from film the maximum variation in optical densities should be less than 10%. Using region of interest analysis, values should be within a range of 10% of each other.
P	**Scaling errors**	The measured distance x and y should agree within 3% of the actual distance. All calculated aspect ratios should be within 1.00 ± 0.003
P	**Blurring**	No blurring should be present. If blurring is present on all plates this suggests the reader is at fault, whilst imperfections in individual plates may also lead to blurring. If blurring remains on a region of a plate after clearing it should not be used clinically.
P	**Limiting Spatial Resolution**	For the 45^0 angled test objects the resolved line pairs per mm. should be >1.2/2p where p is the pixel dimension in mm. In the scan and sub-scan directions the limiting resolution should be >0.85/2p. These measurements should be used to set a baseline for future QA tests.
N/P	**Threshold Contrast Detail Detectability**	The results of this test are used to set a baseline for future QA tests. Results could be compared to those from other similar systems if available.
P	**Laser Beam Function**	The edge should be continuous across the full length of the image. Stair step characteristics should be uniform across the length of the image. Regions of over or undershoot of the scan lines indicate a timer or laser beam modulation problem. Ruler edges should be straight and continuous without any under or over shoot of the scan lines in light to dark transitions.
N/P	**Moire′ Patterns**	No Moire′ patterns should be visible. If Moire′ patterns are visible with a particular grid, it should not be used with the CR plates. The cause of Moire′ patterns may be the failure of the motion of moving grids or insufficient grid density.
P = Pass, **F** = Fail, **N/A** = Not Applicable, **N/P** = Not Performed		

CR Image Display Monitor Calibration

Location: 1st Floor Sirintorn Building, Rajavithi Hospital
Date: Jul 26, 2008
Manufacturer (Monitor): TOTOKU, Monochrome LCD ME 351i
3M pixel, 20.8 inch, Japan.

(Densitometer "puck"): Japan
Model number: MDL2110A
Serial number: M398C03623

Result	Testing Variables
P	White level (500±5.0 cd/m^2)
P	Black level (0.2±0.6 cd/m^2)
P	Gamma DICOM GSDF(Grayscale Standard Display Function)
P	High Spatial Contrast
P	Low Spatial Contrast
P	Geometric Distortion
P	Brightness Uniformity
P	Reading Room Condition

Monitor Luminance Measurement
-Max Luminance 409.94 cd/m^2
-Min Luminance 0.72 cd/m^2

Ambient Viewing luminance Measurement
-Ambient light 50 lux

APPENDIX B

IMAGE QUALITY CRITERIA

Chest PA Projection

1. Diagnostic Requirements

1.1. Performed at full inspiration (as assessed by the position of the ribs above the diaphragm — either 6 anteriorly or 10 posteriorly) and with suspended respiration.
1.2. Symmetrical reproduction of the thorax as shown by central position of the spinous process between the medial ends of the clavicles.
1.3. Medial border of the scapulae to be outside the lung fields.
1.4. Reproduction of the whole rib cage above the diaphragm.
1.5. Visually sharp reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels.
1.6. Visually sharp reproduction of:
(a) the trachea and proximal bronchi,
(b) the borders of the heart and aorta,
(c) the diaphragm and lateral costo-phrenic angles.
1.7. Visualiszation of the retrocardiac lung and the mediastinum.
1.8. Visualization of the spine through the heart shadow.

Skull PA Projection or AP Projection if PA not Possible

1. Diagnostic Requirements

1.1. Symmetrical reproduction of **the skull**, particularly cranial vault, orbits And petrous bones.
1.2. Projection of the apex of the petrous temporal bone into the centre of the orbits.
1.3. Visually sharp reproduction of the frontal sinus, ethmoid cells and apex of the petrous temporal bones and the internal auditory canals.
1.4. Visually sharp reproduction of the outer and inner lamina of the cranial vault.

Skull Lateral Projection

1. Diagnostic Requirements

1.1. Visually sharp reproduction of the outer and inner lamina of the cranial vault, the floor of the sella, and the apex of the petrous temporal bone.
1.2. Superimposition respectively of the contours of the frontal cranial fossa, the lesser wing of the sphenoid bone, the clinoid processes and the external auditory canals.
1.3. Visually sharp reproduction of the vascular channels, the vertex of the skull and the trabecular structure of the cranium.
1.4. Superimposition of the mandibular angles and ascending rami.

Lumbar Spine AP/PA Projection

1. Diagnostic Requirements

1.1. Visually sharp reproduction, as a single line, of the upper and lower-plate surface in the centred beam area
1.2. Visually sharp reproduction of the pedicles.
1.3. Reproduction of the intervertebral joints.
1.4. Reproduction of the spinous and transverse processes.
1.5. Visually sharp reproduction of the cortex and trabecular structures.
1.6. Reproduction of the adjacent soft tissues, particularly the psoas shadows.
1.7. Reproduction of the sacro-iliac joints.

Lumbar Lateral Projection

1. Diagnostic Requirements

1.1. Visually sharp reproduction, as a single line, of the upper and lower-plate surfaces with the resultant visualization of the intervertebral spaces.
1.2. Full superimposition of the posterior vertebral edges.
1.3. Reproduction of the pedicles and the intervertebral foramina.
1.4. Visualization of the spinous processes.
1.5. Visually sharp reproduction of the cortex and trabecular structures.

KUB AP Projection

1. Diagnostic Requirements

1.1. Reproduction of the area of the whole urinary tract from the upper pole of the kidney to base of the bladder
1.2. Reproduction of the kidney outlines
1.3. Visualisation of the psoas outlines
1.4. Visually sharp reproduction of the bones

Cervical Spine AP Projection

No report from image quality criteria (EU)

APPENDIX C

TRAINING PROGRAM

โครงการอบรมเชิงปฏิบัติการเรื่อง **การควบคุมปริมาณรังสีและคุณภาพของภาพด้วยระบบคอมพิวเตอร์ (CR) ในการถ่ายภาพทางรังสีทั่วไป**
(Optimization of Radiation Dose and The Image Quality on Computed Radiographic Image in Routine Simple Projections)

ห้องประชุมปาริชาติ ชั้น 11 อาคารเฉลิมพระเกียรติฯ โรงพยาบาลราชวิถี
วันพฤหัสบดีที่ 22 พฤษภาคม พ.ศ. 2551

08.00 - 8.15	**เปิดงาน** พญ.ศิริพรรณ กัลยาณรุจ หัวหน้ากลุ่มงานรังสีวิทยา (หรือผู้แทน)
08.15 - 10.15	Principles of CR and DR, and applications รศ.ดร.อัญชลี กฤษณจินดา
10.15 - 10.30	เครื่องดื่มและอาหารว่าง
10.30 – 11.00	Performance of good radiographic technique รศ.ดร.อัญชลี กฤษณจินดา , คุณเพ็ชรลีย์ สุวรรณประดิษฐ์
11.00 - 12.30	Quality criteria for diagnostic radiographic image and criteria for radiation dose to the patient รศ.ดร.อัญชลี กฤษณจินดา
12.30 – 13.30	อาหารกลางวัน
13.30 - 14.30	The causes of image retake รศ.ดร.อัญชลี กฤษณจินดา , คุณเพ็ชรลีย์ สุวรรณประดิษฐ์
14.30 - 15.30	Guideline on radiation dose to the patient รศ.ดร.อัญชลี กฤษณจินดา
15.30 - 17.00	**ภาคปฏิบัติ** (เครื่องดื่มและอาหารว่างในระหว่างภาคปฏิบัติ) รศ.ดร.อัญชลี กฤษณจินดา , คุณเพ็ชรลีย์ สุวรรณประดิษฐ์
17.00	**ปิดงาน**

Multiple choice question (MCQ)

Pre Test/ Post Test: May 22, 2008
Name……..
Choose the correct answer:

MCQ1
Related to radiation protection (RP):
a) RP is not applicable to patients.
b) RP is aimed exclusively for workers.
c) A doctor can only request a certain number of radiation examinations because of the limitation principle.
d) One of the aims of RP is to avoid the deterministic effects of ionization radiation.
e) One of the aims of RP is to reduce the probability of deterministic effects of ionizing radiation.

MCQ2
Related to the system of radiation protection:
a) Justification is not applied in medical exposures.
b) Limitation is not applied in medical exposures.
c) Optimization is not applied in medical exposures.
d) ALARA criterion aims to give a summary of the contraindicated situations.
e) There is also a minimum dose limit that everyone should receive to be healthy.

MCQ3
Related to dose limits:
a) Public have a higher limit because they do not receive an "extra" dose because of their occupation.
b) Skin equivalent dose limit for occupational exposed is 500 mSv/year.
c) Dose limits do not consider neither the type of occupation nor the country.
d) Calculating dose limits, we always have to add the natural background radiation (about 2-3 mSv/year).
e) Pregnant woman cannot be exposed to any ionizing radiation, even if it is a medical exposure.

MCQ4
A guidance (or reference) level in diagnostic radiology:
a) Is a dose limit.
b) Is applicable to individual patients.
c) Should always be used in parallel to image quality evaluation.
d) Is clear border between a good and a bad examination.
e) Is a dose level that should be never exceeded.

MCQ5
The patient dose for a CT examination of the chest:
a) Is a value much higher than the dose in a PA chest radiograph.
b) Is a value comparable to the dose in a PA+LAT chest radiographs.
c) Is independent of the number of acquired slices.
d) Is lower than the dose received in simple radiographs if the kV is maintained at 140 kV
e) Is in a range of 40-60 mSv.

MCQ6

A medical exposure:

a) Always has a dose limit settle from the patient size.
b) Includes occupational exposures of the people working in medical installations.
c) Includes exposures incurred knowingly and willingly by individuals such as family and close friends helping either in hospital or at home in the support and comfort of patients.
d) Dose not include exposure incurred by volunteers as part of a program of biomedical research.
e) Is only the exposure received by patients for diagnostic or treatment.

MCQ7

The collimation of the X-Ray beam:

a) Is a good practice to reduce patient dose and to improve image quality.
b) Should be avoided if a good image quality is needed.
c) Is equivalent to a good filtration of the beam.
d) Is not necessary if a compressor is used.
e) Reduces the patient dose but gives poor image quality.

MCQ8

A good radiographic technique includes:

a) The use of low kV and high mAs to reduce patient dose.
b) The use of high kV if the image contrast is good enough.
c) The use of high kV to improve the image contrast.
d) The use of low mA and long exposure time.
e) The use of low kV and low mA in every cases.

MCQ9

A grid improves the quality of diagnostic X-Rays primarily by:

a) Attenuating primary photons.
b) Attenuating Compton scattered photons.
c) Attenuating electrons produced by Compton scatter.
d) Attenuating electrons produced by Photoelectric effect.
e) Attenuating coherently scattered photons.

MCQ10

Which of the following does not reduce patient dose (for the same optical density on the film)?

a) The use of screen.
b) Using high kVp.
c) The use of a high ratio grid.
d) All of the above, since none reduce patient dose.

MCQ11

The evaluation of image quality:

a) Can only be made with test objects.
b) Can only be made with clinical images.
c) Should never be done together with patient dose measurements.
d) Should be done with test objects and clinical images.
e) Is only a subjective parameter. It cannot provide objective indicators.

APPENDIX D

Backscatter factor (BSF)

BSF and HVL (Half value layer) were required for each value of kVp. The appropriate data from Petoussi-Hens was chosen as shown in Table 1

Table1 BSF data and actual values used. All for 25 x 25 cm. field, ICRU tissue, 3mm Al filtration. Value in italics is extrapolated or interpolated

kVp	HVL	BSF	Calculated BSF
60			*1.34*
65			*1.36*
70	**2.64**	**1.38**	**1.38**
75			*1.39*
80	**3.04**	**1.41**	**1.41**
85			*1.42*
90	**3.45**	**1.44**	**1.44**
95			*1.45*
100	**3.88**	**1.46**	**1.46**
120	**4.73**	**1.49**	**1.49**
125			*1.51*

APPENDIX E

1. CASE RECORD FORM

1.1. Form_A: Table for grading image quality and summarize the results for one month and the specific x-ray rooms

Form_A

Room					
Date					
Radiologist (code)					
Id	**Organ/site/view**	**Image quality grading**			**Cause**
		A- accept clearly	**B**- accept with some remark	**C**- should be rejected	

1.2. **Form_B:** Table for reject analysis and image quality grading

Time period of the analysis(mm-yy)	From …to…….	
At the level of **Radiological technologist** (code no.)		
Number of images used during 1 month		
Number of images rejected by radiological technologist		
Percent of image reject by radiological technologist		
Cause analysis of retake	Number	Percent
__ Patient positioning		
__ Motion		
__ Artifacts		
__ Field size misplacement		
__ Others (exposure error)		
Total		100

1.3. **Form_C:** Table for measurements and calculations for dose

Room						
Radiological technologist (Code)						
Chest/Patient ID	**Thickness (cm.)**	**kVp**	**mAs**	**FSD (cm.)**	**ESAK (mGy)**	**ESD (mGy)**
1.						
2.						
3.						
Abdomen/Patient ID						
1.						
2.						
3.						

APPENDIX F

STATISTIC ANALYSIS DATA

1. Normal distribution data testing

Using One-Sample Kolmogorov-Smirnov test from SPSS application program tested the distribution of data of two groups, before and after the training, from Room No.4, Table 1-3, and Room EMS, Table 4-6**.**

Table 1 One-Sample Kolmogorov-Smirnov test of data from *Room No. 4*

		ESD (mGy)					
		Chest_Be	Chest_Af	Abd_Be	Abd_Af	CSP_ Be	CSP_ Af
N		35	35	23	23	9	9
Normal Parameters(a,b)	Mean	.2346	.1691	3.3391	3.0296	.3200	.2856
	Std. Deviation	.06652	.03760	.98574	.72177	.07246	.08338
Most Extreme Differences	Absolute	.158	.196	.136	.147	.265	.374
	Positive	.158	.196	.136	.147	.265	.374
	Negative	-.103	-.119	-.104	-.101	-.199	-.253
Kolmogorov-Smirnov Z		.935	1.160	.650	.704	.795	1.123
Asymp. Sig. (2-tailed)		.346	.136	.792	.704	.552	.161

a Test distribution is Normal.

b Calculated from data.

Table 2 One-Sample Kolmogorov-Smirnov test of data, from *Room No.4*, continue from Table 1

		ESD (mGy)			
		LSP_AP_Be	LSP_AP_Af	LSP_LAT _Be	LSP_LAT _Af
N		15	15	20	20
Normal Parameters(a,b)	Mean	3.0213	2.7200	8.9265	8.3230
	Std. Deviation	.94742	.62617	.88625	1.58842
Most Extreme Differences	Absolute	.213	.261	.153	.211
	Positive	.213	.261	.153	.211
	Negative	-.160	-.116	-.133	-.097
Kolmogorov-Smirnov Z		.824	1.011	.684	.942
Asymp. Sig. (2-tailed)		.506	.259	.738	.337

a Test distribution is Normal**.**

b Calculated from data.

Table 3 One-Sample Kolmogorov-Smirnov test of data, from *Room No. 4*, continue from Table 2

		ESD (mGy)			
		Skull_PA_Be	Skull_PA_Af	Skull_LAT_Be	Skull_LAT_Af
N		3	3	3	3
Normal Parameters(a,b)	Mean	1.9367	1.7433	1.7133	1.4867
	Std. Deviation	.16773	.05132	.38280	.34443
Most Extreme Differences	Absolute	.364	.269	.283	.359
	Positive	.364	.269	.283	.258
	Negative	-.262	-.199	-.207	-.359
Kolmogorov-Smirnov Z		.630	.466	.490	.622
Asymp. Sig. (2-tailed)		.822	.982	.970	.833

a Test distribution is Normal.
b Calculated from data.

Table 4 One-Sample Kolmogorov-Smirnov test of data, *Room EMS*

		ESD (mGy)					
		CXR_Be	CXR_Af	Abdo_Be	Abd_Af	CSP_Be	CSP_Af
N		37	37	35	35	9	9
Normal Parameters(a,b)	Mean	.3616	.2451	2.8446	2.8146	.2478	.3300
	Std. Deviation	.05058	.05640	.57329	.55646	.03667	.02000
Most Extreme Differences	Absolute	.268	.138	.189	.195	.408	.469
	Positive	.224	.111	.189	.195	.272	.309
	Negative	-.268	-.138	-.103	-.098	-.408	-.469
Kolmogorov-Smirnov Z		1.633	.840	1.118	1.151	1.225	1.408
Asymp. Sig. (2-tailed)		.010	.480	.164	.141	.099	.038

a Test distribution is Normal.
b Calculated from data.

Table 5 One-Sample Kolmogorov-Smirnov test of data, *from Room EMS*, continue from Table 4

		ESD (mGy)			
		LSP_AP_Be	LSP_AP_Af	LSP_LAT_Be	LSP_LAT_Af
N		16	16	19	19
Normal Parameters(a,b)	Mean	2.2013	1.9581	8.7921	7.8968
	Std. Deviation	.72774	.81102	1.08089	1.26112
Most Extreme Differences	Absolute	.157	.280	.296	.162
	Positive	.124	.185	.296	.162
	Negative	-.157	-.280	-.110	-.121
Kolmogorov-Smirnov Z		.628	1.122	1.292	.708
Asymp. Sig. (2-tailed)		.825	.161	.071	.698

a Test distribution is Normal.
b Calculated from data.

Table 6 One-Sample Kolmogorov-Smirnov test of data, *from Room EMS*, continue from Table 5

		ESD (mGy)			
		Skull_PA_Be	Skull_PA_Af	Skull_LAT_Be	Skull_LAT_Af
N		3	3	2	2
Normal Parameters(a,b)	Mean	1.5700	1.2633	1.5750	1.2000
	Std. Deviation	.21794	.02517	.34648	.14142
Most Extreme Differences	Absolute	.343	.219	.260	.260
	Positive	.343	.219	.260	.260
	Negative	-.246	-.189	-.260	-.260
Kolmogorov-Smirnov Z		.595	.380	.368	.368
Asymp. Sig. (2-tailed)		.871	.999	.999	.999

a Test distribution is Normal.
b Calculated from data.

2. Paired T-test testing

Table 7 Descriptive statistics from *Room No.4*

	N	Mean ESD (mGy)	Std. Deviation	Minimum	Maximum
Chest_Be	35	.2346	.06652	.15	.39
Chest_Af	35	.1691	.03760	.11	.23
Abdomen_Be	23	3.3391	.98574	2.06	5.23
Abdomen_Af	23	3.0296	.72177	2.00	4.60
Cervical_Be	9	.3200	.07246	.24	.45
Cervical_Af	9	.2856	.08338	.23	.44
L-sp_AP_Be	15	3.0213	.94742	2.08	5.36
L-sp_AP_Af	15	2.7200	.62617	1.97	4.04
L-sp_LAT_Be	20	8.9265	.88625	7.43	10.65
L-sp_LAT_Af	20	8.3230	1.58842	6.16	11.36
Skull_PA_Be	3	1.9367	.16773	1.83	2.13
Skull_PA_Af	3	1.7433	.05132	1.70	1.80
Skull_LAT_Be	3	1.7133	.38280	1.40	2.14
Skull_LAT_Af	3	1.4867	.34443	1.66	1.71

Table 8 Paired samples test from *Room No.4*

		Paired Differences					t	df	Sig.
		Mean ESD (mGy)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Chest_PA_Be Chest_PA_Af	.0654	.06080	.01028	.0445	.0863	6.367	34	.000
Pair 2	Abdomen_Be Abdomen_Af	.3096	.88496	.18453	-.0731	.6923	1.678	22	.108
Pair 3	Cervical_Be Cervical_Af	.0344	.04187	.01396	.0023	.0666	2.468	8	.039
Pair 4	L-sp_AP_Be L-sp_AP_Af	.3013	.93175	.24058	-.2147	.8173	1.253	14	.231
Pair 5	L-sp_LAT_Be L-sp_LAT_Af	.6035	1.10873	.24792	.0846	1.1224	2.434	19	.025
Pair 6	Skull_PA_Be Skull_PA_Af	.1933	.11846	.06839	-.1009	.4876	2.827	2	.106
Pair 7	Skull_LAT_Be Skull_LAT_Af	.2267	.72390	.41794	-1.5716	2.0249	.542	2	.642

Table 9 Descriptive statistics from *Room EMS*

	N	Mean	Std. Deviation	Minimum	Maximum
Chest_Be	37	.3616	.05058	.22	.40
Chest_Af	37	.2451	.05640	.15	.40
Abdomen_Be	35	2.8446	.57329	2.06	3.99
Abdomen_Af	35	2.8146	.55646	1.92	4.24
Cervical_Be	9	.3448	.03667	.17	.27
Cervical_Af	9	.3300	.02000	.29	.34
L-sp_AP_Be	16	2.2013	.72774	1.01	3.54
L-sp_AP_Af	16	1.9581	.81102	.71	3.03
L-sp_LAT_Be	19	8.7921	1.08089	7.33	10.85
L-sp_LAT_Af	19	7.8968	1.26112	6.42	10.37
Skull_PA_Be	3	1.5700	.21794	1.42	1.82
Skull_PA_Af	3	1.2633	.02517	1.24	1.29
Skull_LAT_Be	2	1.5750	.34648	1.33	1.82
Skull_LAT_Af	2	1.2000	.14142	1.10	1.30

Table 10 Paired samples test from *Room EMS*

		Paired Differences					t	df	Sig.
		Mean ESD (mGy)	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Chest_PA_Be Chest_PA_Af	.1165	.06374	.01048	.0952	.1377	11.117	36	.000
Pair 2	Abdomen_Be Abdomen_Af	.0300	.53898	.09110	-.1551	.2151	.329	34	.744
Pair 3	Cervical_Be Cervical_Af	-.0822	.01716	.00572	-.0954	-.0690	-14.375	8	.000
Pair 4	L-sp_AP_Be L-sp_AP_Af	.2431	.41716	.10429	.0208	.4654	2.331	15	.034
Pair 5	L-sp_LAT_Be L-sp_LAT_Af	.8953	.49057	.11254	.6588	1.1317	7.955	18	.000
Pair 6	Skull_PA_Be Skull_PA_Af	.3067	.19399	.11200	-.1752	.7886	2.738	2	.112
Pair 7	Skull_LAT_Be Skull_LAT_Af	.3750	.20506	.14500	-1.4674	2.2174	2.586	1	.235

APPENDIX G

ข้อมูลสำหรับผู้ป่วย (Patient Information Sheet)

การศึกษาทางห้องปฏิบัติการ การหาปริมาณรังสีและคุณภาพของภาพในการถ่ายภาพรังสีทั่วไปด้วยระบบคอมพิวเตอร์เปรียบเทียบผลการศึกษาก่อน และหลังการอบรม

เรียน ผู้ป่วยทุกท่าน

ท่านเป็นผู้ที่ได้เข้ารับการบริการถ่ายภาพรังสีทั่วไปด้วยระบบคอมพิวเตอร์ของงานรังสีวินิจฉัยผู้ป่วยนอก ชั้น 1 ตึกสิรินธรท่านเป็นผู้ที่ได้รับเชิญจากนักรังสีการแพทย์ นักฟิสิกส์ การแพทย์และรังสีแพทย์ให้เข้าร่วมการศึกษาวิจัยถึงปริมาณรังสีที่ท่านจะได้รับ รวมถึงการประเมินคุณภาพของภาพรังสีภายหลังจากการเข้ารับบริการถ่ายภาพรังสีทั่วไป ก่อนที่ท่านจะตกลงเข้าร่วมการศึกษาดังกล่าว ขอเรียนให้ท่านทราบถึงเหตุผลและรายละเอียดของการศึกษาวิจัยในครั้งนี้

ปัจจุบันการเข้ารับบริการถ่ายภาพรังสีทั่วไป ณ งานรังสีวินิจฉัย ผู้ป่วยนอกชั้น 1 ตึกสิรินธร ได้มีการนำเครื่องมือที่มีเทคโนโลยี่สูงเข้ามาช่วยในการบริการการถ่ายภาพทางรังสีทั่วไปแก่ผู้ป่วย คือ เครื่อง Computed Radiography (CR) ทำให้การบริการรวดเร็วยิ่งขึ้น สามารถปรับแต่งคุณภาพของภาพรังสีให้พอเหมาะต่อการวินิจฉัยโรคมากยิ่งขึ้น สามารถบริหารจัดการข้อมูลภาพเข้าสู่โครงข่ายคอมพิวเตอร์ของกลุ่มงานรังสีวิทยา และโครงข่ายของโรงพยาบาลราชวิถี ซึ่งจะเป็นประโยชน์ต่อท่านเมื่อเข้ารับบริการการตรวจวินิจฉัยและมารับการรักษากับโรงพยาบาลราชวิถีในอนาคต

ในการนำเครื่องCR มาใช้ในการถ่ายภาพรังสีทั่วไปนี้ ทั้งนักรังสีการแพทย์ นักฟิสิกส์การแพทย์และรังสีแพทย์ คาดหวังว่าจะสามารถลดปัญหาการถ่ายภาพรังสีซ้ำซ้อนเนื่องมาจากความเข้าใจและการใช้เครื่องมืออุปกรณ์อย่างมีประสิทธิภาพของนักรังสีการแพทย์ซึ่งจะส่งผลให้มีการลดปริมาณรังสีที่ผู้ป่วยจะได้รับให้ลดน้อยลง คงไว้ซึ่งคุณภาพของภาพทางรังสีที่ยังเป็นที่ยอมรับของรังสีแพทย์และแพทย์ผู้ทำการตรวจรักษา มีการใช้ปริมาณรังเท่าที่จำเป็น ซึ่งเป็นมาตรการการป้องกันอันตรายจากรังสีโดยตรงที่ทุกคนและทุกหน่วยงานที่เกี่ยวข้องกับรังสีตระหนักเป็นอย่างดี ดังนั้นจึงเกิดแนวคิดในการศึกษา การหาปริมาณรังสีและคุณภาพของภาพในการถ่ายภาพรังสีทั่วไปเพื่อให้ปริมาณรังสีที่ผู้ป่วยได้รับไม่เกินปริมาณมาตรฐานสากลขณะเดียวกันคงไว้ซึ่งคุณภาพของภาพสำหรับการวินิจฉัยที่ถูกต้องและแม่นยำ

ดังนั้นเพื่อให้สามารถบรรลุวัตถุประสงดังกล่าวในการให้บริการการถ่ายภาพทางรังสีทั่วไปแก่ท่านทุกครั้ง นักรังสีการแพทย์จำเป็นต้องได้รับข้อมู ลเกี่ยวกับท่านก่อนการถ่ายภาพรังสีทั่วไป ได้แก่ การตรวจสอบอายุ ชั่งน้ำหนัก วัดส่วนสูง และวัดความหนาบริเวณกึ่งกลางของส่วนของร่างกายที่แพทย์ผู้ทำการตรวจรักษาต้องการให้เข้ารับบริการการถ่ายภาพทางรังสีทั่วไป

หากท่านตกลงที่จะเข้าร่วมการศึกษาวิจัยครั้งนี้ จะมีข้อปฏิบัติร่วมดังนี้

-ท่านผู้เข้าร่วมการศึกษานี้ เป็นผู้ป่วยที่ต้องมีคำร้องขอเข้ารับการวินิจฉัยด้วยภาพทางรังสีทั่วไปจากแพทย์ผู้ตรวจเท่านั้น เป็นผู้ได้รับเกียรติที่ผ่านเกณฑ์การคัดเลือกกลุ่มตัวอย่างตามแบบฟอร์มโครงร่างงานวิจัยที่ได้รับอนุมัติจากคณะกรรมการพิจารณาจริยธรรมแล้ว รวมทั้งสิ้นอย่างน้อย 788 การตรวจภายในระยะเวลา 3 เดือนของการเก็บข้อมูล

-ท่านไม่ต้องเสียค่าใช้จ่ายใดๆเพิ่มเติมจากค่าตรวจปกติของการถ่ายภาพวินิจฉัยด้วยภาพรังสีทีแพทย์ผู้ตรวจส่งตรวจ

-การศึกษานี้เป็นการเก็บข้อมูลที่จำเป็นในการกำหนดปริมาณรังสีแก่ผู้ป่วยที่เข้ารับการวินิจฉัยด้วยภาพรังสีที่พึงปฏิบัติตามปกติวิสัยของการถ่ายภาพทางรังสีทั่วไป

-การศึกษานี้เป็นการเก็บข้อมูลความบกพร่องที่อาจเกิดขึ้นบนภาพรังสี มิได้เป็นการให้หรือเว้นการให้สิ่งใดแก่ผู้เข้าร่วมการศึกษาวิจัย

-การศึกษานี้เป็นความพยายามเพิ่มคุณภาพและมาตรฐานการใช้เครื่องมืออุปกรณ์ในการถ่ายภาพรังสีทั่วไป

-ก่อนการถ่ายภาพรังสีทั่วไปทุกครั้ง ท่านจะได้รับทราบข้อมูลของการถ่ายภาพทางรังสีทั่วไปจากนักรังสีการแพทย์ที่ทำการเก็บข้อมูลตามความเป็นจริง อันได้แก่ ส่วนของร่างกายที่จะได้รับการถ่ายภาพรังสี จำนวนภาพทางรังสีที่เกิดขึ้น และวิธีการปฏิบัติตัวระหว่างการรับถ่ายภาพทางรังสี

-ในระหว่างการรับถ่ายภาพทางรังสีทั่วไปท่านต้องปฏิบัติตามคำแนะนำของนักรังสีการแพทย์ผู้ปฏิบัติงานเพื่อป้องกันการถ่ายภาพรังสีซ้ำ

-กรณีจำเป็นต้องทำการถ่ายภาพรังสีทั่วไปซ้ำ อันเนื่องมาจากสาเหตุใด ๆก็ตาม นักรังสีการแพทย์ผู้ปฏิบัติงานจะต้องชี้แจงเหตุผลตามความเป็นจริงแก่ท่านทุกครั้งก่อนทำการถ่ายภาพรังสีซ้ำ

-การเข้าร่วมการศึกษาครั้งนี้ เป็นไปโดยสมัครใจท่านอาจปฏิเสธที่จะเข้าร่วมการศึกษาครั้งนี้ โดยไม่กระทบต่อการให้บริการการตรวจวินิจฉัยของท่านที่จะได้รับจากนักรังสีการแพทย์ นักฟิสิกส์การแพทย์และรังสีแพทย์ หรือผู้ให้บริการท่านอื่นๆ

ประการสำคัญที่ท่านควรทราบคือ

ผลของการศึกษานี้จะใช้สำหรับวัตถุประสงค์ทางวิชาการเท่านั้น

ขอรับรองว่าจะไม่มีการเปิดเผยชื่อของท่านตามกฎหมาย

หากท่านมีปัญหาหรือข้อสงสัยประการใด กรุณาติดต่อนส.สุณี ล้ำเลิศเดชา สาขาวิชาฉายาเวชศาสตร์ ภาควิชารังสีวิทยา คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

โทร. 02-2564418 ซึ่งยินดีให้คำตอบแก่ท่านทุกเมื่อ

ขอขอบพระคุณในความร่วมมือของท่านมา ณ ที่นี้

ใบยินยอมเข้าร่วมการศึกษา (Consent Form)

Study No.....

เลขที่ผู้ป่วย..... ชื่อและนามสกุล.....

ข้าพเจ้าได้รับทราบจากนักรังสีการแพทย์ผู้ทำการเก็บข้อมูลตามความเป็นจริง ซึ่งได้ลงนามด้านท้ายของหนังสือนี้ ถึงวัตถุประสงค์และวิธีการเข้าร่วมการศึกษานี้เป็นที่เรียบร้อยแล้ว

ข้าพเจ้ายินดีให้นำข้อมูลภาพทางรังสีและข้อมูลที่จำเป็นในการวิเคราะห์ของข้าพเจ้า แก่นักรังสีการแพทย์ผู้ทำการเก็บข้อมูล เพื่อประโยชน์ในการศึกษาวิจัยครั้งนี้ ได้แก่

อายุ_____ ปี น้ำหนัก _____ กิโลกรรม ส่วนสูง _____ ซม.
ความหนาบริเวณกึ่งกลางของส่วนของร่างกายที่ได้รับการถ่ายภาพรังสี _____ซม.

ข้าพเจ้ายินดีเข้าร่วมการศึกษาครั้งนี้โดยสมัครใจ โดยไม่มีการบังคับหรือให้อามิสสินจ้างใดๆ และข้าพเจ้าอาจปฏิเสธการเข้าร่วมการศึกษานี้เมื่อใดก็ได้ โดยไม่จำเป็นต้องแจ้งเหตุผล

ข้าพเจ้าได้รับทราบ และเข้าใจข้อมูลจากนักรังสีการแพทย์ผู้ให้บริการถ่ายภาพรังสีจะปฏิบัติตามคำแนะนำขณะเข้ารับบริการถ่ายภาพรังสีทั่วไปตามใบคำร้องขอของแพทย์ผู้ส่งตรวจ และยอมรับฟังเหตุผลของการถ่ายภาพทางรังสีซ้ำ หากเกิดกรณีสุดวิสัยแห่งความบกพร่องของภาพรังสีทุกประการ
สุดท้ายนี้ข้าพเจ้ายินดีเข้าร่วมการศึกษานี้ ภายใต้เงื่อนไขที่ระบุไว้ข้างต้น

วันที่.....เดือน.....พ.ศ.2551 .....
เอกซเรย์ผู้ป่วยนอก ชั้น 1 ตึกสิรินธร (.....)
ลงนามผู้ป่วยหรือผู้ปกครองโดยชอบด้วยกฎหมาย

....
(.....) (.....)
พยาน นักรังสีการแพทย์ผู้ทำการเก็บข้อมูล

....
(.....) (…..นส.สุณี ล้ำเลิศเดชา.....)
นักรังสีการแพทย์ผู้ให้บริการถ่ายภาพรังสี ผู้ทำการวิจัย

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