การเปรียบเทียบ ปริมาณรังสีเฉลี่ยที่ต่อมน้ำนมได้รับและคุณภาพของภาพโดยใช้เครื่องดิจิทัลแมมโมแกรมที่มีคุณสมบัติต่างกัน 2 เครื่อง

นางสาววลัยภรณ์ เขื่อนแก้ว

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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ปีการศึกษา 2552

COMPARISON OF AVERAGE GLANDULAR DOSE AND IMAGE QUALITY BETWEEN TWO DIFFERENT TARGET-FILTER COMBINATIONS OF FULL-FIELD DIGITAL MAMMOGRAPHY SYSTEMS

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A Thesis Submitted in Partial Fulfillment of the Requirements
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ในปัจจุบัน มะเร็งเต้านม เป็นมะเร็งที่ถูกรวบรวมว่าสูงเป็นอันดับ 1 ในผู้หญิงไทย ในขณะที่มะเร็งปากมดลูกเป็นอันดับ 2 การวินิจฉัยโรคมะเร็งเต้านมทำโดยการถ่ายภาพรังสี ได้ถูกพัฒนาให้มีความเหมาะสมของปริมาณรังสีแก่ผู้ป่วยและมีคุณภาพของภาพที่ดี

วัตถุประสงค์ในการศึกษานี้เพื่อเปรียบเทียบปริมาณรังสีที่ต่อมน้ำนมรวมถึงที่ผิวของเต้านมได้รับ และคุณภาพของภาพโดยการศึกษาอัตราส่วนความคมชัดของภาพกับสัญญาณรบกวนในผู้ป่วยที่เต้านมมีรอยโรคระหว่างเครื่องเอกซเรย์เต้านมระบบดิจิทัล ที่มีเป้าหลอดและตัวกรองรังสีต่างกัน 2 เครื่อง ศึกษาคุณลักษณะของเครื่อง จากการควบคุมคุณภาพ การศึกษานี้ทำในผู้ป่วยหญิงที่มารับการตรวจคัดกรองมะเร็งเต้านม ในท่า ซีซี ทั้ง 2 ข้าง ปริมาณรังสีที่ต่อมน้ำนมและที่ผิว บันทึกจากผลที่แสดงบนหน้าจอ อัตราส่วนของความคมชัดและสัญญาณรบกวนเมื่อคำนวณจากผู้ป่วยที่มีรอยโรค 2 กลุ่มคือ กลุ่มที่มีหินปูนและมีก้อนเนื้อ ตามเกณฑ์การคัดผู้ป่วยเข้าทำการศึกษา ผลคือที่ความหนาของเต้านม 28-59 มิลลิเมตร ปริมาณรังสีเฉลี่ยที่ต่อมน้ำนมและที่ผิวของเต้านมได้รับคือ 1.75 และ 11.24 มิลลิเกรย์ตามลำดับ สำหรับเป้าและแผ่นกรองรังสีของหลอดเอกซเรย์ได้แก่โมลิบดีนัม-โมลิบดีนัม สำหรับทังสเตน-โรเดียมคือ 1.43 และ 5.25 มิลลิเกรย์ ซึ่งปริมาณรังสีลดลงถึง 18.29 และ 53.29 เปอร์เซ็นต์ตามลำดับ เมื่อเปลี่ยนเป้าและแผ่นกรองรังสีจากโมลิบดินัม-โมลิบดินัม เป็นทังสเตน-โรเดียม เมื่อความหนาของเต้านมเป็น 70-91มิลลิเมตร ปริมาณรังสีที่ได้รับคือ 2.01 และ 14.77 มิลลิเกรย์ สำหรับโมลิบดินัม-โรเดียม และ 1.86 กับ 8.77 มิลลิเกรย์ ตามลำดับ สำหรับทังสเตน-ซิลเวอร์ ปริมาณรังสีเฉลี่ยที่ต่อมน้ำนมและที่ผิวของเต้านมได้รับลดลง 7.46 และ 40.62 เปอร์เซ็นต์ตามลำดับ เมื่อเปลี่ยนจากโมลิบดินัม-โรเดียม เป็นทังสเตน-ซิลเวอร์ ค่าเฉลี่ยของอัตราส่วนความคมชัดและสัญญาณรบกวนสำหรับการตรวจพบหินปูนเมื่อใช้โมลิบดินัม-โมลิบดินัม เปรียบเทียบกับ ทังสเตน-โรเดียม คือ 0.86± 0.66 และ 1.05 ± 0.75ตามลำดับ ความคมชัดต่ำสุดที่ตรวจพบเท่ากันคือ 0.04 ส่วนเปอร์เซ็นต์ความคมชัดคือ 9.52 ± 7.35 กับ 12.44± 7.74 และเปอร์เซ็นต์ความคมชัดต่ำสุดที่ตรวจพบคือ 0.37 และ 0.58 เปอร์เซ็นต์ สำหรับการใช้โมลิบดินัม-โรเดียม เปรียบเทียบกับ ทังสเตน-ซิลเวอร์ ค่าเฉลี่ยของอัตราส่วนความคมชัดและสัญญาณรบกวนคือ 1.04±0.69 และ1.59±1.14 ความคมชัดต่ำสุดที่ตรวจพบคือ 0.21และ 0.12 ตามลำดับ เปอร์เซ็นต์ความคมชัดคือ 10.49±5.79 และ16.82±10.86 ส่วน ค่าเฉลี่ยอัตราส่วนของความคมชัดและสัญญาณรบกวนสำหรับการตรวจพบก้อนเนื้อเปรียบเทียบระหว่างโมลิบดินัม- โมลิบดินัม กับ ทังสเตน-โรเดียมคือ 1.36±1.35 และ 1.06±0.79 ค่าความคมชัดต่ำสุดที่ตรวจพบคือ 0.21และ0.22 ตามลำดับ เปอร์เซ็นต์ความคมชัด คือ 10.5±7.75 และ 13.84±8.15 ค่าเฉลี่ยอัตราส่วนความคมชัดและสัญญาณรบกวน จากโมลิบดินัม-โรเดียม คือ 1.4±1.05 ค่าความคมชัด ต่ำสุดที่ตรวจพบคือ 0.15 เปอร์เซ็นต์ความคมชัด คือ 11.68±7.19 ส่วนทังสเตน-ซิลเวอร์ ไม่มีข้อมูลผู้ป่วย สรุป ปริมาณรังสีที่ต่อมน้ำนมได้รับต่อ 1 ภาพ สำหรับ ท่า ซีซี ใช้กริด มีค่าน้อยกว่า 3 มิลลิเกรย์ตามมาตรฐานของ วิทยาลัยรังสีแพทย์แห่งสหรัฐอเมริกา ช่วงข้อมูลความหนา 60-69 มิลลิเมตรได้ถูกคัดออกไป การใช้เป้าและแผ่นกรองรังสีที่ต่างกันทำให้ปริมาณรังสีมีความแตกต่างกัน อย่างมีนัยสำคัญทางสถิติ (ค่าp<0.05) ส่วนคุณภาพของภาพในเรื่องอัตราส่วนความคมชัดและสัญญาณรบกวน สำหรับการตรวจพบหินปูนและก้อนเนื้อระหว่างเครื่อง 2 ระบบมีความสัมพันธ์กันแต่ไม่มีนัยสำคัญทางสถิติ ความคลาดเคลื่อนในการคำนวณ อัตราส่วนความคมชัดและสัญญาณรบกวน อาจเกิดขึ้นจาก การวาดขอบเขตของรอยโรคมากเกินไปโดยเฉพาะในบริเวณที่เป็นก้อน

ภาควิชา รังสีวิทยา ลายมือชื่อนิสิต .....

สาขาวิชา เวชศาสตร์ ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก .....

ปีการศึกษา 2552

5174825130: MAJOR MEDICAL IMAGING

KEYWORDS: FULL FIELD DIGITAL MAMMOGRAPHY / AVERAGE GLANDULAR DOSE / AMORPHOUS SELENIUM / TUNGSTEN.

WALAIPORN KHUENKAEW: COMPARISON OF AVERAGE GLANDULAR DOSE AND IMAGE QUALITY BETWEEN TWO DIFFERENT TARGET-FILTER COMBINATIONS OF FULL-FIELD DIGITAL MAMMOGRAPHY SYSTEM. THESIS ADVISOR: ASSOC.PROF. ANCHALI KRISANACHINDA, Ph.D., 117pp.

Breast cancer is the leading cancer in Thai women while the cancer of the cervix is the second rank. The mammographic system had been developed for the optimization of the radiation dose and image quality to patient.

The purpose of the study is to compare the average glandular dose (AGD), entrance surface air kerma (ESAK) and image quality in terms of contrast to noise ratio (CNR) with breast pathology between two different target-filter combinations of full-field digital mammographic systems (FFDM). The system performance was studied for quality control program. The study involves 441 women undergoing screening mammographic examinations in cranio-caudal (CC) view on both breasts. The AGD and ESAK displayed on the monitor were verified and recorded. The CNR was calculated for both groups with pathology of calcifications (macro-micro) or mass who met the eligible criteria. Results: The AGD was 1.75 mGy for Mo-Mo and 1.43 mGy for W-Rh, the ESAK was 11.24 mGy for Mo-Mo and 5.25 mGy for W-Rh at the compress breast thickness (CBT) of 28-59 mm. When the CBT was 70-91 mm, the AGD was 2.01 mGy for Mo-Rh and 1.86 mGy for W-Ag. The ESAK was 14.77 mGy for Mo-Rh and 8.77 mGy for W-Ag. The AGD was reduced to 18.29% when changed from Mo-Mo to W-Rh and 7.46% when changed from Mo-Rh to W-Ag target filter combinations. The ESAK was reduced to 53.29% when Mo-Mo was changed to W-Rh and 40.62% when Mo-Rh was changed to W-Ag target- filter combinations. The mean CNR for calcification detection from Mo/Mo target/filters was 0.86 ±0.66, the minimal contrast detectable was 0.04, the percent contrast was 9.52±7.35. The mean CNR of W/Rh was 1.05±0.75 minimal contrast detectable was 0.04, the percent contrast was 12.44 ±7.74, the percent contrast minimal detectable was 0.58, higher than Mo/Mo of 0.37. For CBT 70-91 mm, Mo/Rh target, the mean CNR was 1.04±0.69, minimal contrast detectable was 0.21, the percent contrast was 10.49±5.79, the mean CNR of W/Ag is 1.59±1.14 minimal contrast detectable was 0.12 the percent contrast was 16.82 ±10.86. The mean CNR for mass detection from Mo/Mo target/filters was 1.36±1.35 minimal contrast detectable was 0.21, the percent contrast was 10.5±7.75, the mean CNR of W/Rh was 1.06±0.79 minimal contrast detectable was 0.22, the percent contrast was 13.84±8.15. The mean CNR for mass from Mo/Rh target/filters combination was 1.4±1.05, the minimal contrast detectable was 0.15, the percent contrast was 11.68±7.19. There was no patient data for W/Ag target. Discussions and Conclusions: The AGD per view for CC view with grid was less than the dose reference level (DRL) of 3.0 mGy as recommended by the ACR. The CBT for data range 60-69 mm was excluded. Different target-filter combinations affect on AGD significantly for the p- value of less than 0.05. The image quality in terms of CNR for calcification and mass detection between two systems was correlated but not significantly different. The errors in calculating CNR may occur from the oversize of ROI drawing over the lesion especially in mass.

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LIST OF ABBREVIATIONS

Abbreviations	Terms
AAPM	American Association of Physicists in Medicine
ACR	American College of Radiologists
AEC	Automatic Exposure Control
AGD	Average Glandular Dose
a-Se	Amorphous selenium
CBT	Compressed Breast Thickness
CC	Cranio- Caudal
cm	Centimeter
CV	Coefficient of variation
DICOM	Digital Imaging and Communications in Medicine
DQE	Detective Quantum Efficiency
ESAK	Entrance Surface Air Kerma
ESD	Entrance Skin Dose
ESE	Entrance Skin Exposure
FDA	Food and Drug Administration
FFDM	Full Field Digital Mammography
HVL	Half-Value Layer
ICRU	International Commission on Radiation Units and Measurements
Ka	air Kerma
kVp	kilo-voltage peak
LCIS	Lobular carcinoma in situ

Abbreviations	Terms
mAs	Milliampere second
MGD	Mean glandular dose
mGy	Milligray
MLO	Mediolateral oblique
mm	Millimeter
Mo	Molybdenum
MQSA	Mammography Quality Standards Act
MTF	Modulation Transfer Function
NCI	National cancer institute
N	Newton
p	p-value
PMMA	Polymethylmethacrylate
QA	Quality Assurance
QC	Quality Control
Rh	Rhodium
s	Second
SD	Standard Deviation
SFM	Screen Film Mammography
SID	Source to Image Distance
SPSS	Statistical Package for the Social Sciences
W	Tungsten

CHAPTER I

INTRODUCTION

1.1 Background and rationale

Breast cancer is the most common cancer which found in 1 out of 8 American women. Now the breast cancer is also the leading cancer for Thai women while the cancer of the cervix is the second rank [1]. The estimated incidence rate of 1 per 5000 women of breast cancer is found in Thai women at the age of 40 years and above especially for those who live in Bangkok and at the vicinity area. As they are well educated and follow the guidelines of the healthcare screening for pap smear test annually, the incidence of the cancer of the cervix is decreasing. In contrast, the life style of the women in Bangkok is most likely similar to the western women leading to the higher incidence of breast cancer. Therefore, the factors influence the incidence of breast cancer should be determined. Mammogram is one of the screening tests accepted in the developed countries as it is very sensitive for the early detection of the breast cancer. Furthermore, the specificity and sensitivity of the mammogram are also high and well accepted all over the world. For the early detection of breast cancer, the survival rate could be increasing up to 98 percent.

From the past to present, the mammography system had been developed for better image quality and the optimization of the radiation dose to patient. The Full Field Digital Mammography (FFDM) System could be operated as automatic exposure control and manual systems [2]. The advanced digital detector converts the analog to digital directly, and the images could be forwarded to image archiving system as the DICOM standards and the DICOM Work lists could connect to the Hospital Information System (HIS) to PACS. The breast compression paddle can be operated automatically and manually which also control the automatic collimation. The x-ray tube using Mo-Mo, Mo-Rh, target – filter systems were selected according to the breast thickness to reduce the patient radiation dose.

New technology has been introduced for the flat panel detector and X-ray tube with tungsten target-silver filter for FFDM. The main idea for using tungsten anode is the dose reduction to the breast tissue while maintaining the same image quality [3]. The radiation doses to patient and image quality are still the challenging in studying for new technology of full field digital mammography.

1.2 Hypothesis

1.2.1 H_0: No differences in average glandular dose and image quality when using two FFDM target-filter combinations.

1.2.2 H_a: There are differences in average glandular dose and image quality when using two FFDM target-filter combinations.

1.3 Objectives

1.3.1 To study and compare the average glandular dose between two FFDM systems of different target-filter combinations.

1.3.2 To evaluate and compare the image quality in the terms of contrast-to noise ratio (CNR).

1.4 Definition

Average Glandular Dose:	The average absorbed dose in the glandular tissue excluding skin in a uniformly compressed breast of 50% adipose 50% glandular tissue composition (ICRP 1987)
Anode Target Material:	The primary material in the anode of an x-ray source.
Compression Thickness:	The average thickness of the breast when compressed, if compression has been applied during x-ray exposure.
Half Value Layer:	Thickness of aluminum required to reduce the X-Ray output by a factor of two.
Accumulated Average Glandular Dose:	Average Glandular Dose to a single breast accumulated over multiple images.
Hospital Information Systems (HIS):	A hospital information system variously also called clinical information system (CIS) is a comprehensive, integrated information system designed to manage the administrative, financial and clinical aspects of a hospital. This encompasses paper-based information processing as well as data processing machines.
Digital Imaging and Communications in Medicine (DICOM):	The field of medical informatics for exchanging digital information between medical imaging equipment (such as radiological imaging) and other systems.

Picture Archiving and Communication System (PACS): Picture archiving and communication systems are computers, commonly servers or NAS boxes, dedicated to the storage, retrieval, distribution and presentation of images. The medical images are stored in an independent format. The most common format for image storage is DICOM (Digital Imaging and Communications in Medicine).

CHAPTER II

REVIEW OF RELATED LITERATURES

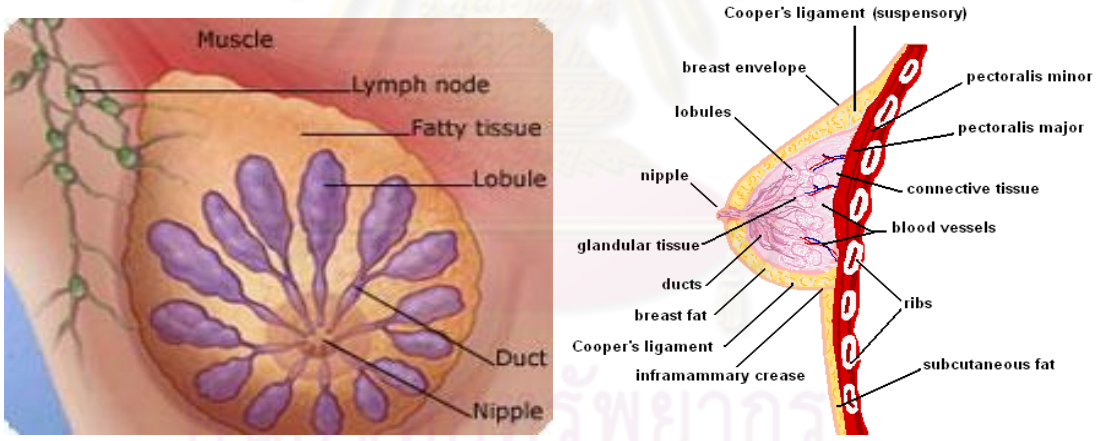
2.1 Theory

2.1.1 The normal structure of the breast [4].

Women's breast consists of 15-20 sectors (share), around the nipple area like spokes in a wheel. Inside of the shares are areas of the smaller sizes, called slices. At the end of each segment are tiny "bubbles" in which milk is produced. These elements are connected by miniature "tubes", called ducts, where the milk comes to the nipple as shown in Figure 2.1.

That is at the center of pigmented area called areola. In the areola, tiny glands called Montgomery glands provide lubrication of the nipple during breastfeeding. Intervals between the slices and ducts are filled with fatty tissue. No muscles inside the breast, but under each of the gland are pectoral muscles covering the rib.

In each of the mammary glands are the blood vessels, as well as vessels in which the liquid flows, known as lymphomas. Lymph circulating in the body by a network of vessels, or lymphatic system, carrying cells that help the body to fight infections. A lymph vessel flows to the lymph nodes.



A. B.

Figure 2.1 The normal structure of the breast. (Breast cancer centre, 2009)
A. Cross-section view of breast structure. B. Lateral view of breast structure

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- **Cooper's ligament**: the connective tissue that attaches the mammary gland to the overlying skin.
- **Pectoralis major**: the larger chest muscle that arises from the collar bone, the sternum, most or all of the ribs, and the external oblique muscle and is inserted into the humerus bone of the upper arm. This is the largest muscle of the chest and it pulls the arm forward.

- **Pectoralis minor**: A smaller chest muscle that lies beneath the pectoralis major that arises from the third, fourth and fifth ribs, and is inserted into the process of the shoulder blade. This muscle stabilizes the shoulder blade.
- **Connective tissue**
- **Blood vessels**
- **Ribs**
- **Subcutaneous fat**: fat that is just underneath the skin
- **Inframammary crease**: the fold or crease under the breast where the breast meets the upper abdomen.
- **Breast fat:** fatty tissue found above the glandular tissue of the breast.
- **Ducts**: a duct is any tube that carries the secretion of a gland. In the breast, the ducts are lactiferous ducts or milk ducts
- **Glandular tissue**
- **Nipple**: the protuberance of the mammary gland that contains the openings of the milk ducts open and from which milk is drawn
- **Lobules**: the part of the breast where milk is produced. The lobules are gathered into lobes.
- **Breast envelope**: the skin that surrounds the structure of the breast.

The breast is attached to the chest wall by the breast envelope and connective tissue, and the Cooper's ligaments. During any surgery on the breast, care must be taken so as not to sever these ligaments. If the connective tissue or ligaments are disrupted, the breasts can droop.

2.1.2 Breast cancer screening methods [5].

There are three main methods of screening for breast cancer: mammography, clinical breast examination, and breast self-examination.

Mammography — A mammogram is a breast x-ray examination which is the best screening test reducing the risk of breast cancer. Early concerns about the radiation exposure from mammograms have lessened with the use of modern mammography equipment that exposes the breast to extremely low levels of radiation. The current level of radiation exposure is unlikely to significantly increase the risk of developing breast cancer.

Technique - Each breast is x-rayed individually. The breast is flattened by compression device between two panels, to more easily seen abnormalities. This can be uncomfortable for only a few seconds. Mammograms are most uncomfortable just before or at the beginning of the menstrual period; women should try to avoid scheduling their mammogram at these times, if possible.

Findings - Breast cancer cannot be diagnosed by mammography alone. Further testing e.g., ultrasound or biopsy is recommended if a mass, new calcium deposits, or other abnormal findings is shown. These findings do not always mean that a cancer has been found. 11 percent of mammograms performed in the United States require additional evaluation; more than 90 percent of these cases were not cancer.

The abnormalities on mammograms are calcifications and masses. Types of calcification are macro and micro calcifications.

- Macro-calcifications are large calcium deposits that most often represent degenerative changes in the breast occur with aging or with previous trauma or inflammation. Macro-calcifications are common, particularly in women over the age of 50, and generally do not require a biopsy.
- Micro-calcifications are small specks of calcium that sometimes suggest the presence of breast cancer. Depending upon the shape and pattern of micro-calcifications, a biopsy of the affected area is recommended or a repeat mammogram in three to six months.

Clinical breast examination — Clinical breast examination is performed by a health care provider and is typically performed at the yearly physical examination. Healthcare providers usually inspect the breasts for any changes in size or shape and then palpate (feel) the breasts and the area under both arms for any change in texture or lumps.

Both clinical breast examination and mammography are important. The studies show that about 50 percent of breast cancer found on screening was detected by both examination and mammography. 5 to 10 percent are detected with examination and missed by mammography, and about 40 percent are detected by mammography and missed by examination.

Breast self-examination — Breast self-examination is a means of detecting changes in individual breasts. It typically is performed at the same time each month. The best time to perform breast self-examination is about one week after the menstrual period ends, when the breasts are least lumpy. In postmenopausal women, the same day for each month is recommended.

Most studies have not found breast self-examination to be beneficial in reducing the risk of breast cancer. However, one large randomized trial found breast self-examination did result in women undergoing more breast biopsies for benign lumps. Nevertheless, some women feel that practicing breast self-examination on a regular basis improves their ability to detect subtle changes that would otherwise not have been noticed. Breast self-examination is not a substitute for mammography or breast examination by a health care professional.

The studies suggest that performing breast self-examination correctly is important. Women who want to perform self-examinations should ask their health care provider to demonstrate how to do it and how to tell the difference between normal tissue and suspicious lumps. Instructions for performing self breast examination are provided in Table 2.1.

Table2.1. Breast self-examination**.**

Breast self-examination is best done about a week after the menstrual period. Women who are postmenopausal may perform the exam any time. Some women perform once per month while others do it less frequently or not at all; these are all acceptable choices.
- Start by standing in front of a mirror. Place both hands on the hips. Examine the breasts for changes in skin color, texture, dimpling, and note how the nipples look. Some women have inverted nipples (nipples point inwards instead of out); this is not abnormal as long as this appearance does not change over time.
- Lift the hands above the head and turn to the side to examine the entire breast in front of the mirror. If necessary, lift each breast to examine the skin under the breast.
- Lie down and put the left hand above the head. Use the right hand to examine the left breast. You will use the tips of the fingers to press the breast tissue against the chest, moving in a circular motion.
- Start by feeling the breast tissue closest to the middle of the chest. Move the hand down the chest in a line, moving the fingers in a circular motion as you go. At the base of the breast, begin moving the hand back up towards the head, continuing to move the tips of the fingers in a circular motion.
- Continue this up and down pattern until you have covered the entire breast and under arm area.
- It is normal to feel the bony ribs in the chest. Abnormal lumps may feel firm, have irregular edges, and may feel "stuck" to the chest. If you are unsure if a lump is normal or abnormal, make an appointment to see a healthcare provider for an examination.
- Switch hands and repeat the examination on the right breast.

2.1.3 Breast cancer detection technologies [6].

The apparent strengths and weaknesses of the new breast cancer detection technologies is evaluated. However, the experimental evidence available for most new breast cancer detection technologies was not strong enough to support definitive conclusions about their ultimate clinical value and use. None of the newer technologies have been studied to the same extent as conventional mammography.

Advances in breast cancer detection technology include improvements to current techniques, new ways to image the breast, and new detection strategies aimed at finding distinctive "molecular signatures" of a pre-malignant or malignant breast tumor. The Food and Drug Administration (FDA) has approved some of these new techniques for clinical use, but many are in earlier stages of development and have not been used outside a research setting.

2.1.3.1 Digital Mammography

Unlike film mammography devices that produce an x-ray image of the breast directly on photographic film, digital mammography devices, which still require breast compression, capture the x-ray image digitally. An array of detectors creates a digitized image that can be viewed and manipulated on a computer screen. In theory, this could enable better detection of tumors obscured by the dense breast tissue frequently seen in younger women. The ability to enlarge or adjust the contrast of questionable areas without requiring new x-ray exposure may facilitate the detection of lesions that have been missed by film mammography. The technology could also improve screening mammography by allowing electronic storage, retrieval, and transmission of mammograms. However, one important limitation of digital mammograms is that the images are not as finely detailed as film mammograms.

2.1.3.1.1 Direct conversion detectors

These systems use a layer of amorphous selenium as the x-ray converter coupled to an amorphous silicon readout array. However, in this case, the panel pixels do not incorporate a photodiode. The x-ray photons are converted directly to electronic charge in a selenium layer that is then read out by the thin film transistor (TFT) array, as shown in Figure 2.2. A high electric field is maintained across the selenium layer, which ensures that the charge is collected without a high degree of lateral spread. This improves the sharpness of the images compared with phosphor based systems in which light spreads laterally. Nominal pixel size is typically 70 μm or 85 μm. As the shape and structure of amorphous selenium devices are similar to those of amorphous silicon devices, they are also termed flat panel detectors.

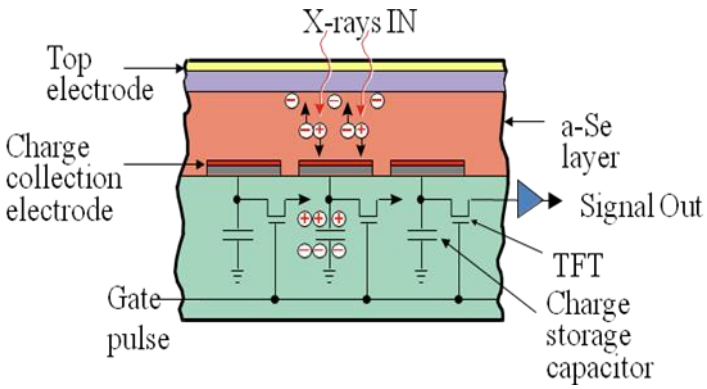


Figure 2.2 Digital image receptor direct conversion technology. (Prasadg, 2006)

2.1.3.1.2 X-ray tube-target and spectrum

Subject contrast is the relative difference in X-ray exposure at the entrance plane of the image receptor transmitted through one part of the breast and through an adjacent part resulting from X-ray attenuation properties. Attenuation is strongly dependent on the X-ray energies (spectrum) determined by the target material, kVp, and filtration (either inherent in the tube or added).

Molybdenum (Mo) target X-ray units generate characteristic radiation at 17.9 and 19.5 keV as displayed in figure 2.3. A Mo filter 0.025 mm to 0.03 mm thick strongly suppresses photon energies less than 15 keV and those greater than 20 keV, yielding high subject contrast and avoiding excess radiation dose for 2 to 5 cm breasts imaged at typical voltages of 25 to 28 kVp.

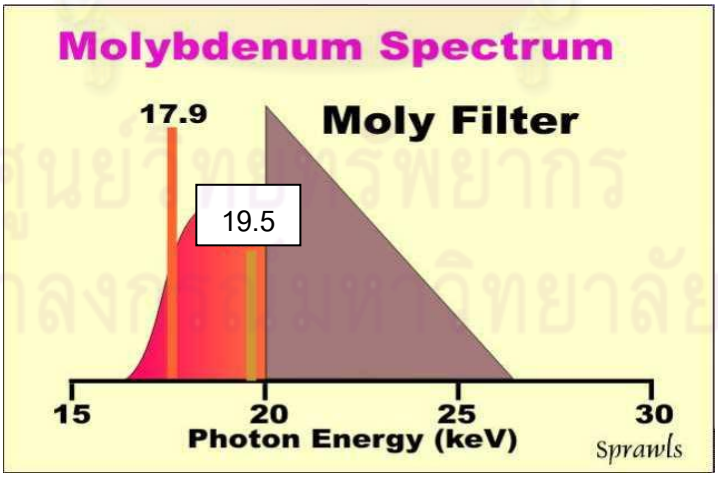


Figure 2.3 Characteristic radiations of molybdenum spectrum at 17.9 and 19.5 keV. (Sprawls, 1998)

The optimum spectrum to produce the best balance between contrast sensitivity and radiation dose for an average size breast is one with most of the radiation with photon energies below about 20 keV. However, there is considerable Bremsstrahlung above this energy. In the typical mammography equipment a molybdenum filter is used to remove that undesirable part of the spectrum. This is an application of a filter that works on the "K edge" principle. It absorbs radiation that is above the K-edge energy that corresponds to the binding energy of the electrons in the K shell of the molybdenum atom. (Figure 2.3)

Tungsten (W) target tubes are advantageous for short exposure times. Without useful characteristic radiation, the energy spectrum is optimized for mammography with Mo and Rh filters, typically of 0.05 mm thickness or greater. Greater filter thickness is necessary to attenuate useless L X-rays emanating from the W target. Careful choice of kVp and filter material can yield excellent results in terms of contrast and breast dose.

The spectrum of the significant characteristic radiation from tungsten is shown in figure 2.4. Characteristic radiation produces a line spectrum with several discrete energies, whereas Bremsstrahlung produces a continuous spectrum of photon energies over a specific range. The number of photons created at each characteristic energy is different because the probability for filling a K-shell vacancy is different from shell to shell.

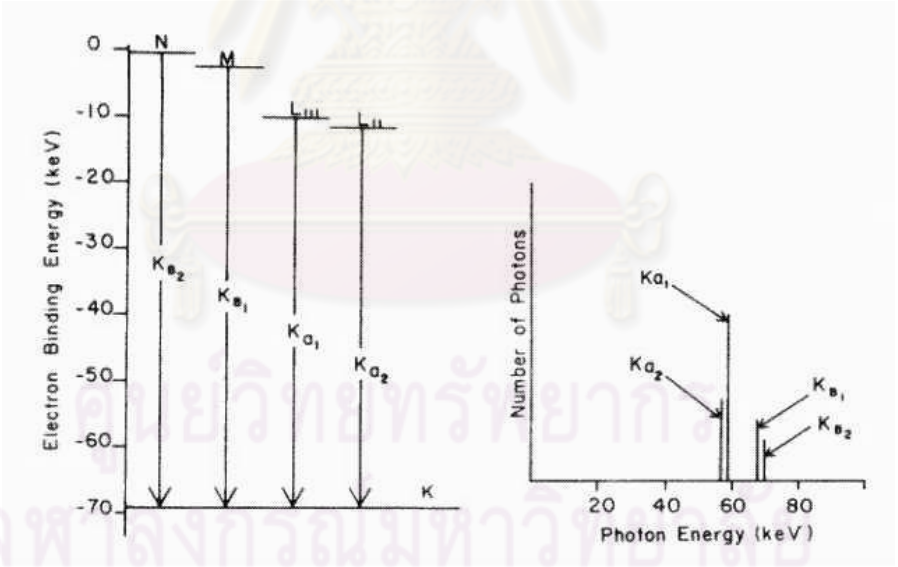


Figure 2.4 Electron energy levels in tungsten and the associated characteristic x-ray spectrum. (Sprawls, 1998)

Tungsten x-ray tube imaging is also particularly well suited to some of the advanced imaging applications in development. The high radiation output of tungsten anodes allows for superior tomosynthesis imaging, where it is desired to create a number of short x-ray pulses during the acquisition, so as to minimize focal spot blur. Another application is the use of dual energy imaging so as to improve the visibility of micro-calcifications, which requires high kVp exposures.

2.1.4 Average Glandular Dose [7].

It is difficult to make a precise determination of the radiation dose to a breast during mammography because of the variations in breast anatomy that are encountered and not being able to insert measuring devices, dosemeters, into the breast. The usual procedure is to make measurements of the exposure to the surface of the breast and then use published tables of dose factors to calculate a quantity that is defined as the Average Glandular Dose (AGD).

The determination of AGD values for a standard reference breast is part of the general quality assurance and procedure evaluation program. The objective is not to adjust the equipment and imaging techniques to produce the lowest possible dose (AGD). It is to use imaging conditions that produce the necessary image quality (primarily contrast sensitivity and visibility of detail) without the use of unnecessary exposure to the patient.

The glandular dose (Dg) was estimated through a semi-empirical method considering the skin entry exposure (X_{ESE}) and the normalized glandular dose (DgN), related by equation 1 proposed by Dance:

$$Dg = DgN.\ X_{ESE} \tag{1}$$

X_{ESE} represents the primary beam entry region air exposure in the phantom, the measurements being performed directly on the primary beam, with the field size slightly greater than the chamber volume (not considering the backscattering). Measurements were performed with the compression device under the primary beam.

The average radiation absorbed dose to glandular breast tissue is accepted as an estimation of the patient dose in mammography.

2.1.5 Image Quality in Mammogram [8].

In mammography, it is most important to consistently produce high-contrast, high resolution images at the lowest radiation dose consistent with high image quality.

Image quality requirements for mammography are:

- High contrast sensitivity
- High detail (low blurring)
- Low visual noise
- Minimal artifacts
- Spatial characteristics (appropriate projections and field of view)

2.1.5.1 Contrast sensitivity

Contrast sensitivity is the characteristics of an imaging process that determines the visibility of objects in the body that have low physical contrast. The anatomical structures and pathologic signs are all soft tissues with physical densities very similar to the adipose background of the breast. The visibility of small calcifications is limited by blurring, but they also require high contrast sensitivity.

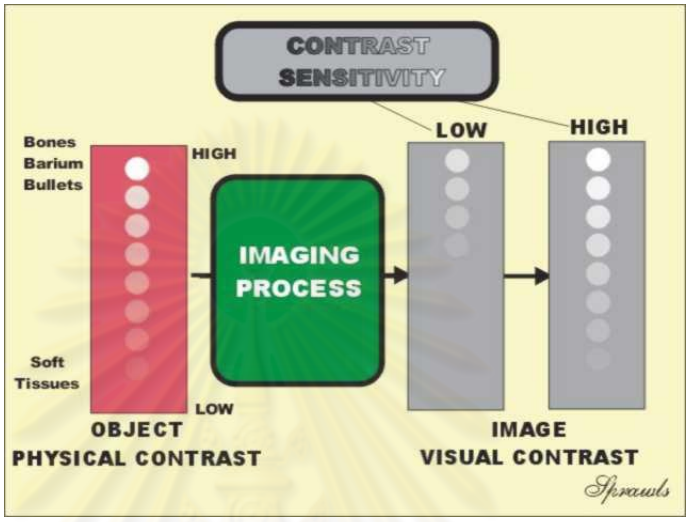


Figure 2.5 The contrast sensitivity characteristics of an imaging process the visibility of objects in the body of the low physical contrast. (Sprawls, 1998)

For the radiographic imaging methods, mammography is designed to have much higher contrast sensitivity than the other radiographic procedures.

The relative contrast sensitivity is one of the characteristics that are tested using the accreditation phantom shown figure 2.6. That is done by counting the number of simulated masses that are visible. The phantom contains a series of five (5) simulated masses decreasing in size (diameter) from the largest (#12) to the smallest (#16) in the lower right corner. However, it is not the diameter that is important; it is the thickness of the masses which is also decreasing as shown figure 2.6. The thickness of a mass determines its physical contrast and the amount of x-ray attenuation it produces. Since we have a series of objects (masses) with varying physical contrasts, it is a useful test device for evaluating contrast sensitivity.

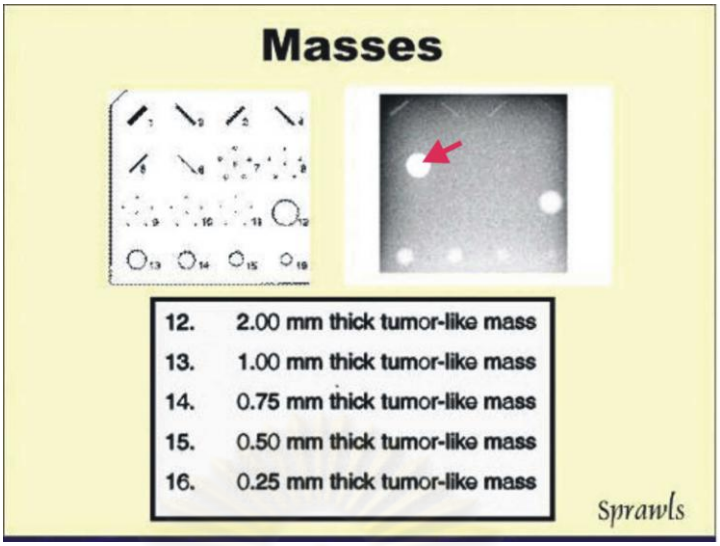
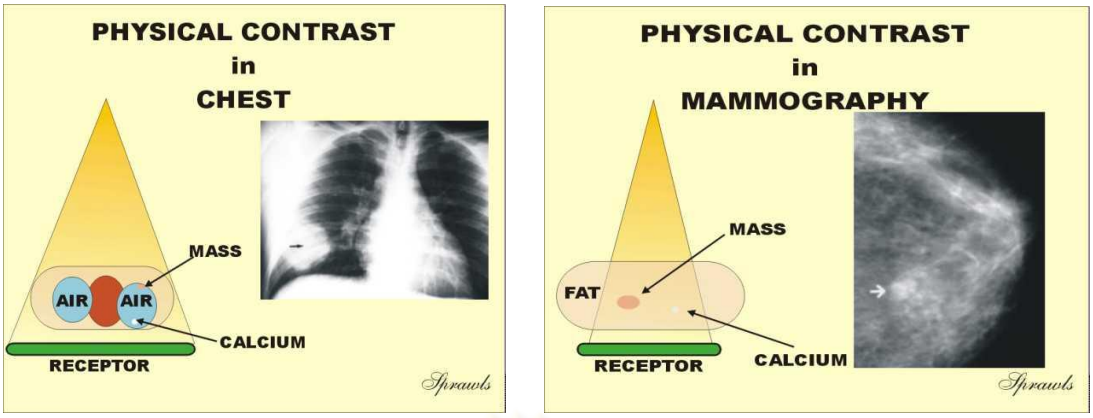


Figure 2.6 The relative contrast sensitivity test by using the accreditation phantom. (Sprawls, 1998)

It is expected to be able to see four (4) masses when the phantom is imaged with conventional mammography equipment operating in a standard protocol. The fifth mass is generally not visible. This does not indicate that the equipment or imaging procedure is defective. It does demonstrate to us that even with high-quality mammography, everything within a breast might not be visualized. The one disk not in the numbered series (arrow) is actually a small disk attached to the outside of the phantom and used to measure overall contrast in the image using a densitometer. A numerical value for the contrast is the difference between the film density values measured in the disk area and the background area near the disk. There are a number of technical factors within mammography that affect contrast sensitivity. These need to be considered when setting up the procedure, processing, and viewing the image.

2.1.5.1.1 Physical contrast

The level of contrast sensitivity that is needed in a specific imaging procedure depends on the amount of physical contrast that is present in the body section being imaged. That varies considerably among the different anatomical locations. It is interesting to consider the two extremes illustrated figure2.7 (A). The chest is a region with very high physical contrast because of the large difference in density between the lungs partially filled with air and the bones. The lungs form a low density background on which most of the other anatomical structures and signs of pathology can be imaged. Chest radiography requires low contrast sensitivity because of the high physical contrast that is present. The first step to achieve low contrast sensitivity is by using high KV values (like 120kV) that produce a very penetrating x-ray beam. The breast is the complete opposite to the chest with respect to contrast. It consists of soft tissues with relatively small differences in density (or atomic number). (figure2.7 (B))



A B

Figure 2.7 The physical contrast. (Sprawls, 1998)
A. Chest B. Mammogram

The adipose tissue does form a "low density" background on which the glandular tissue and signs of pathology can be imaged. However, the differences in density and the physical contrast are very small and a procedure with high contrast sensitivity is required for visualization.

Contrast-to-noise ratio (CNR) is a measure of the detectors ability to distinguish between objects in an image and the image noise.

$$CNR = \frac{\text{Mean pixel value (signal)-mean pixel value (background)}}{\text{Standard deviation (background)}}$$

Signal-to-noise ratio (SNR) compares the level of the desired signal to the level of background noise. A higher SNR provides a better image.

$$SNR = \frac{\text{Mean pixel value-offset in pixel value}}{\text{Standard deviation in pixel value}}$$

2.1.5.1.2 Factors that Affect Film/Screen Contrast Characteristics

- Film Design

For mammography, two film characteristics are conflicting with each other. First, we need a steep characteristic curve because that represents high contrast transfer and contrast sensitivity. However, for the usual range of film densities that can be viewed on a conventional view box, a steep characteristic curve results in reduced latitude. A wide latitude is required to image the rather wide range of exposure coming through the breast. While compression is useful in providing a more uniform breast thickness, and a smaller range of exposure, there is still a considerable range because of other variations in thickness (near the nipple) and in density.

The contrast characteristics for mammography film are different from other radiographic films in order to have both high contrast (that is a steep slope) and wide latitude. This is achieved by designing the film to record contrast over an exposure range that extends to the higher film densities (darkness) compared to general radiographic film.(figure 2.8)

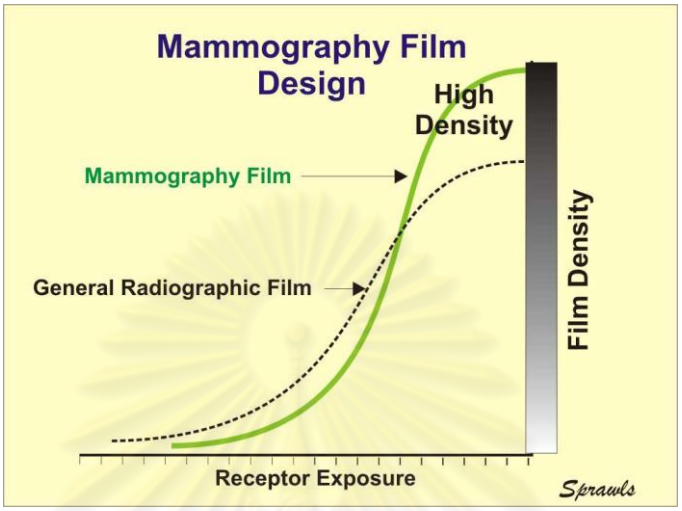


Figure 2.8 The contrast characteristics for mammography film compare with general radiographic films in order to have both high contrast (that is a steep slope) and wide latitude. (Sprawls, 1998)

To utilize this extended contrast characteristic to the full advantage requires two things. The film must be exposed to a relatively high average density (darkness) so that it is centered within the film's extended sensitive range (latitude). This is achieved by calibrating and setting the AEC to produce a relatively high density (a density of 1.7 is illustrated figure 2.9) when imaging a test device (phantom) of uniform thickness.

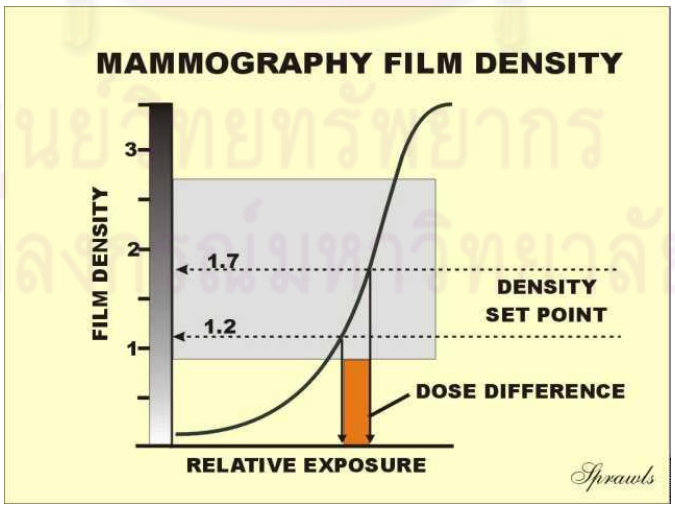


Figure 2.9 Mammography film densities test device (phantom) of uniform thickness. (Sprawls, 1998)

A point about optimization - The average density is set to a lower value of 1.2 as illustrated in figure 2.9 that is more like what is used in general radiography, the dose would be reduced. However, the contrast would be reduced. This is an example where attention must be given to optimizing the contrast to dose relationship. It also illustrates the point that there are times when a certain dose level is needed to achieve the necessary image quality. The second requirement is that the properly exposed mammography film is relatively dark (high density) and must be viewed on a specially designed bright view box.

- Film Exposure Level

Most mammograms are made using Automatic Exposure Control (AEC). The AEC system measures the exposure that reaches the receptor after penetrating the breast and turns the exposure off when the necessary exposure has been delivered to produce the expected film density. While AEC is a valuable function for producing optimum film density and visibility, it does not always produce the "perfect" exposure. There are several potential sources of error that must be considered. Two are associated with the set-up and calibration of the system by the engineers, and two are under the control of the technologist/radiographer

AEC Calibration: the AEC must be calibrated by the engineering staff to produce the desired film density. The calibration is verified by a medical physicist who specifies a density value that is optimum for the specific clinical facility. The calibration is specified in terms of the film density (a value of 1.6 is illustrated figure 2.9) produced when imaging a test device (phantom) of uniform thickness.

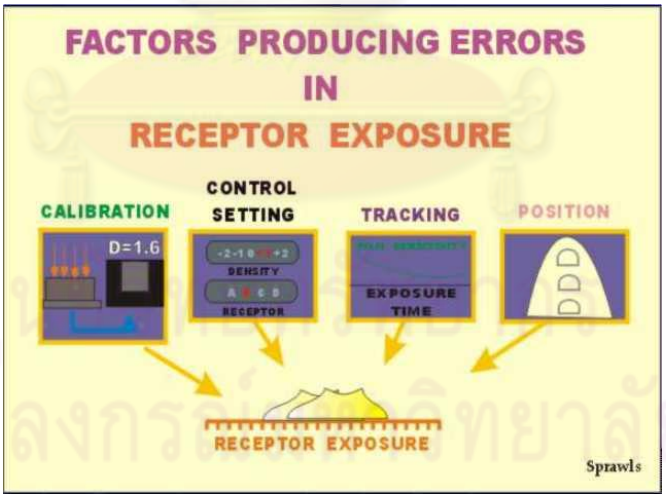


Figure 2.10 The calibration is specified in terms of the film density produced when imaging a test device (phantom) of uniform thickness. (Sprawls, 1998)

AEC Tracking: (Physicist and Engineer Function) Tracking is the ability of the AEC to maintain correct calibration over the range of receptor types, KV values, and exposure times used in a clinical facility. This is generally not a problem with modern mammography equipment but is evaluated periodically by a medical physicist in the context of the QA program.

AEC Sensor Position: Typical mammography systems have multiple radiation sensors, or at least multiple sensor positions, for measuring the exposure reaching the receptor. The film will be exposed to the calibrated density in the anatomical area over the selected sensor or sensor position. The appropriate sensor position should be selected based on breast characteristics, especially the presence of dense areas. An incorrect sensor location can result in an exposure error (too light or too dark) to the film.

Density Control Setting: the radiographer can adjust the "Density" control to change the film density from that produced by the AEC normal setting. Typical settings of the Density control are: (N) normal, +1, +2, +3, -1, -2, -3, etc. Although there is no standard relationship, changing the Density control by one unit will generally increase or decrease the exposure about 15%. The Density control is useful when it appears that the AEC (N) normal setting does not produce the appropriate film density (until it can be recalibrated by the engineer) and when certain breast conditions are better visualized with lighter or darker films. Associated with the Density control is a function for indicating which receptor (film/screen combination) is being used. The AEC must have this information to make the correct exposure.

- Film Processing Level

The formation of a visible image on film is a two-step process. First, the film is exposed to form the invisible latent image and then the film is chemically processed to develop the visible image. Processing is a critical step requiring special attention in mammography because of the many sources of variability and sub-standard processing. The purpose is to take a brief look at the factors associated with variations in mammography film processing. Film processing is a four step process: development, fixing, washing, and drying. It is the development step that converts the exposed film to one with density and contrast. Development is not an instantaneous process but occurs over a period of time (usually about 25 seconds) as the chemicals interact with the exposed silver halide crystals in the film emulsion. The objective is for the development process to continue until the film is fully developed, but not overdeveloped which produces one form of film fog. The final level of development is determined by a combination of physical and chemical factors. These are the factors and conditions that must be addressed when setting up the processing and monitoring (either directly or indirectly through sensitometer) of it in the context of a Quality Assurance Program.

There are two very specific processing goals:

1. An appropriate level of processing so that all (ideally) of the exposed silver halide crystals are converted to black silver and film density. This is necessary to get both maximum contrast and the optimum exposure sensitivity or "speed" (to reduce patient exposure) from the film.
2. Consistent processing so that the film exposure sensitivity does not drift or change with time resulting in exposure errors.

- Viewing Conditions

The display and viewing of the film is the last step in the total process of visualizing the anatomy and pathology within the breast. It can be a "weak link" and reduce much of the contrast sensitivity developed in the other stages of the imaging process. There are three (3) specific factors associated with the viewing that must be addressed.

View box Luminance (Brightness): A characteristic of the human visual system is that maximum contrast sensitivity requires a relatively bright or well illuminated image for viewing. Film mammography presents a special challenge because the films are exposed to a relatively high density, compared to other radiographs, in order to obtain the maximum contrast from the film, as described previously. These darker or more dense films require illumination with an especially bright illuminator or view box in order to enhance the visual contrast sensitivity and visualization of low-contrast objects in the breast. View boxes designed for mammography have brightness values of at least 3500 units compared to around 1500 units for conventional radiography illuminators.

Masking: The advantage of a bright view box brings a problem. If there are uncovered areas around a film this creates a bright light shining right into the eyes of the viewer. This is the bright headlights of oncoming traffic situation. Bright light shining into the eye reduces contrast sensitivity and visibility of relatively low-contrast objects. The solution is to cover or mask the areas around a film.

Room Illumination: Low-level illumination in the film reading room or viewing area increases visual contrast sensitivity as the eyes adapt to the darker environment.

2.1.5.1.3 Factors that Affect Digital Mammography Contrast Characteristics

- Digital Image Processing

Digital mammography provides several advantages over film for optimizing the contrast transfer from the breast to the image display and the maximizing the overall contrast sensitivity.

Three (3) of the major features are shown figure 2.11.

Digital receptor dynamic range. A valuable characteristic of most digital receptors is a constant sensitivity over a wide range of exposures. This is very different from the relatively narrow latitude or dynamic range of film as we have seen earlier. The advantage is that the full exposure histogram will be easily covered by the wide dynamic range and that a considerable variation in exposure to the receptor (exposure error) can be tolerated without loss of contrast. The transfer of exposure contrast into digital image contrast is represented by a linear (straight-line) rather than the steep characteristic curve of film with its limited latitude. The digital image recorded by the typical digital receptor will have relatively low contrast (it would look like a rather gray image) but it will be uniform over the full exposure range. The next

step is to select the exposure range representing the actual image, that is the histogram, and to enhance the contrast by digital processing and windowing.

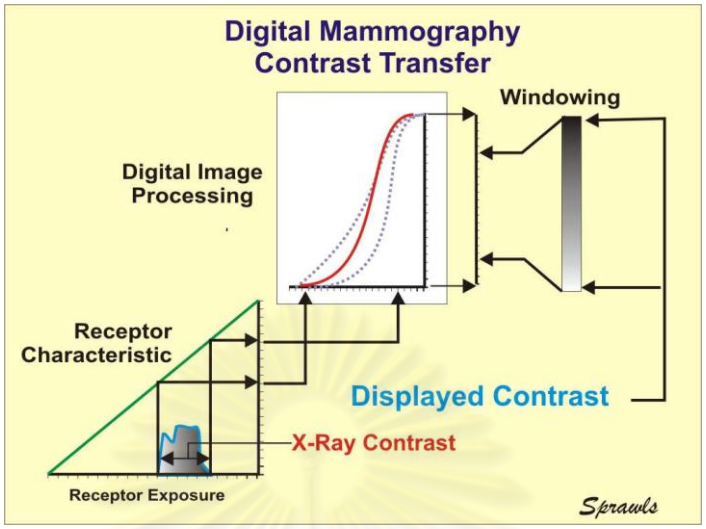


Figure 2.11 The major features of digital mammography contrast transfer. (Sprawls, 1998)

Digital image processing. One of the great advantages of digital imaging is the ability to apply a variety of processing procedures to change the image characteristics, hopefully to improve quality and visibility in most cases. Here we are focusing attention on the contrast. Contrast processing is common in most forms of digital radiography and is used to make the digitally acquired radiographs "look like" more conventional film radiographs with respect to contrast. This processing can be thought of as applying a film characteristic (H & D) curve as illustrated here. The advantage is that the user can select from many different "film characteristics" to meet the needs of specific clinical procedures. For example, in general radiography, one "characteristic curve" type would be appropriate for chest imaging while another would be used for imaging the extremities. In digital mammography the various contrast processing procedures are generally built into the system and might vary to some extent from one manufacturer to another.

- Digital image windowing

Windowing, as used in the display and viewing of most digital images (including CT, MRI, etc) is the last step in optimizing the contrast and visibility of specific objects and structures within an image.

2.1.5.2 Spatial Resolution

Spatial resolution refers to the ability to display 2 separate objects and visually distinguish 1 from the other. The ultimate resolution limit of any digital system is determined by its pixel size. For the same field of view (FOV), spatial resolution is better with a larger image matrix. Noise is limited by the size of the pixel, and the best possible Noise often is defined as the uncertainty in a spatial resolution for an image is the size of the pixel due to random fluctuations in that signal. The smaller the pixels

are, the more that will fit in the image matrix and the greater the spatial resolution. Because one-third of all factors affecting x-ray quality and quantity.

2.1.5.3 Assessment of Image Quality [9].

There are both benefits and risks associated with most medical procedures. Medical imaging, especially imaging that exposes patients to ionizing radiation, is no exception. The goal of medical imaging is to provide the most useful medical information, at the lowest risk commensurate with providing that information. Mammography exposes the breast, one of the tissues most sensitive to ionizing radiation. Therefore, it is important to determine what level of image quality is required to permit appropriate medical decision making and consequently how much radiation is required.

2.2 Literature review

Oduko J.M. et al [10] studied the effect of tungsten-anode x-ray tube on patient dose and image quality in full-field digital mammography, the most dose-efficient, and maintain achievable image quality for all PMMA phantom thickness. Dose and image quality have been evaluated for two types of digital mammography system which the X-ray tubes using tungsten anodes, the Siemens Novation and the Hologic Selenia. For each system, contrast-to-noise ratio and threshold contrast measurements were studied. The optimum exposure settings had been determined for each system to meet the achievable image quality standard of the European Guidelines. For the Selenia system, the dose savings between 9% and 52% were achieved by using a tungsten-target tube, for PMMA thicknesses ranging from 20 to 70mm. For the Novation system, the same range of PMMA thickness simulating breasts, the dose saving was 10% to 50% when using a W/Rh rather than Mo/Mo target-filter combination. When comparing W/Rh with Mo/Rh for the Novation, a modest dose reduction ranging from 4% to 18% was achieved.

Varjonen M. et al [11] studied the optimized target – filter combinations to meet the high image quality and the lowest possible average glandular dose in digital mammography based on amorphous selenium (a-Se) detector technology. The study also provided the recommendations for target-filter combinations in digital mammography for different breast thicknesses. The full field digital mammography (FFDM) system based on a-Se technology, which is also a platform of tomosynthesis prototype, was used in the study. X-ray target – filter combinations, were W–Rh, W–Ag, W–Mo, and W–Sn. The average glandular doses (AGD) were calculated using a specific program, described by Dance et al. [3], the image quality was evaluated by contrast and noise analysis. By using the W–Rh, W–Ag, W–Sn, W–Mo target-filter combinations, it is possible to achieve significantly lower average glandular dose compared to Mo–Mo and Mo–Rh. The average glandular dose reduction was achieved from 40 % to 60 % depending on the selected target-filter combination and the breast thickness. In the future, the evaluation will concentrate to study the effect of higher kVp (> 35 kVp) values, which might be useful in optimizing the dose in digital mammography.

Bernhardt P. et al [12] studied the x-ray spectrum optimization of full-field digital mammography: simulation and phantom study. In contrast to conventional analog screen-film mammography, new flat panel detectors show a high dynamic

range and a linear characteristic curve. Hence, the radiographic technique can be optimized independently of the receptor exposure. It can be exclusively focused on the improvement of the image quality and the reduction of the patient dose. The image quality had been measured by a physical quantity, the signal difference-to-noise ratio (SDNR), and the patient risk by the average glandular dose (AGD). Using these quantities compared the following different setups through simulations and phantom studies regarding the detection of micro calcifications and tumors for different breast thicknesses and breast compositions: monochromatic radiation, three different anode/filter combinations: Mo/Mo, Mo/Rh, and W/Rh, different filter thicknesses, anti-scatter grids, and different tube voltages. For a digital mammography system based on an amorphous selenium detector it turned out that, first, the W/Rh combination is the best choice for all detection tasks studied, second, monochromatic radiation can further reduce the AGD by a factor of up to 2.3, maintaining the image quality in comparison with a real polychromatic spectrum of an x-ray tube, and, third, the use of an anti-scatter grid is only advantageous for breast thicknesses larger than approximately 5 cm.

Gennaro G. et al [13] studied the performance of automatic exposure control in several digital mammography systems. The test procedure proposed by the European Guidelines, requires the measurement of contrast-to-noise ratio (CNR) produced by 0.2 mm Al superimposed on variable polymethyl-methacrylate (PMMA) phantom of different thickness. PMMA layers were exposed by full automatic techniques and average glandular dose (AGD) had been determined. The results demonstrated that AGD values keep below the acceptable limits for all systems at almost all equivalent breast thickness. CNR absolute values per each thickness can significantly vary, depending on characteristics of each type of equipment. The application of limits suggested by the European Guidelines for CNR variation with reference to 50 mm PMMA causes systematic failure for equivalent breast thickness above 50 mm; this may be due to the contradiction between the principles followed by the manufacturers to design the AEC (signal constancy) and those proposed by the European protocol (CNR constancy).

The digital mammography system is set up in the most dose-efficient way, to maintain achievable image quality and have many studies about average glandular dose, image quality, optimizing target-filter combinations etc. Thus the average glandular doses and image quality from digital mammography in Thai people should be studied for the new technology.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Research design

This study is the observational comparative study.

3.2 Research questions

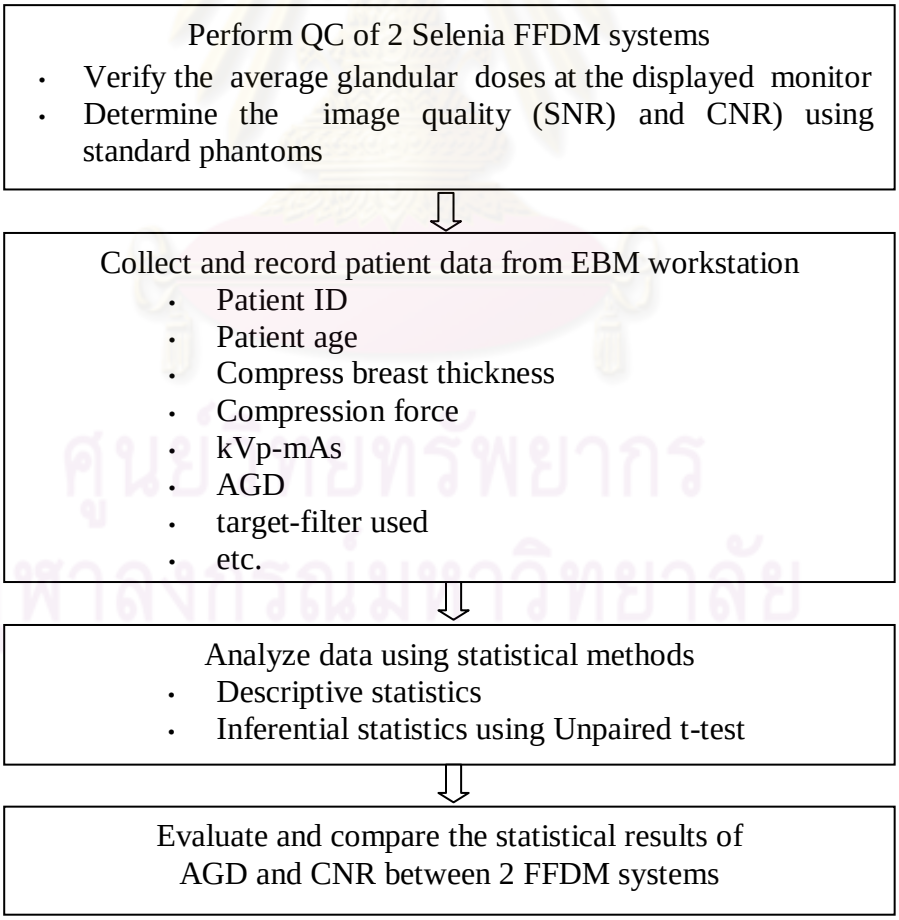
3.2.1 Primary question

Is there any difference in average glandular dose for two different target- filter combinations of FFDM systems?

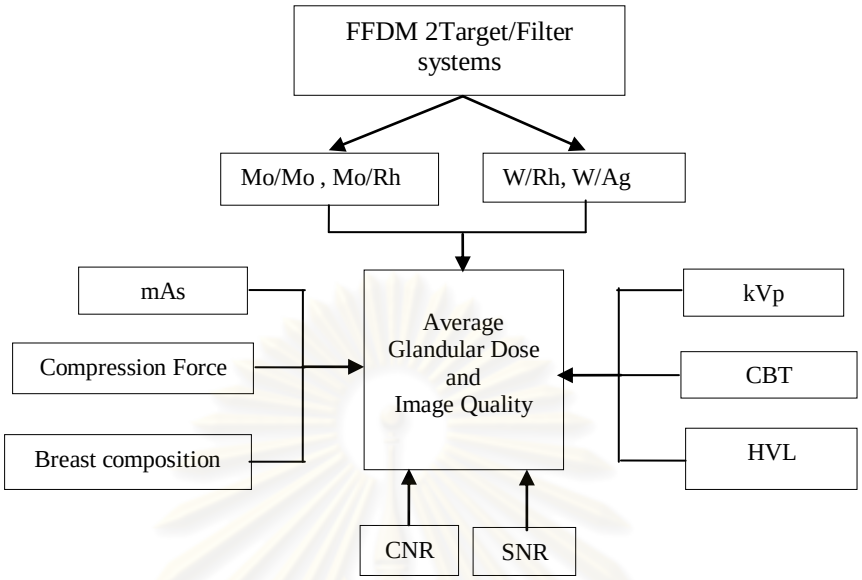
3.2.2 Secondary question

What are the ranges of CNR in images of different thickness between two FFDM systems?

3.3 Research design model



3.4 Conceptual framework



3.5 Keyword

- Full Field Digital Mammography
- Average Glandular Dose
- Amorphous Selenium
- Tungsten.

3.6 The Sample

3.6.1 Target population

Thai female patients who underwent FFDM at King Chulalongkorn Memorial Hospital during 2 periods, April - Aug 2006 for molybdenum target system and April - Aug 2009 for tungsten target system.

3.6.2 Sample Population

Thai female patients who underwent FFDM at King Chulalongkorn Memorial Hospital during the period April – Aug 2006 for molybdenum target system and during the period April - Aug 2009 for tungsten target system. All sample population must meet the following eligible criteria.

Eligible criteria:

Inclusion Criteria:

- Mammographic procedures for screening and diagnosis.
- Cranio - caudal (CC) view for both breasts.
- For image quality evaluation, collect only patients with pathology disorders.

Exclusion Criteria:

- Implant breast
- Breast conservation surgery
- Non AEC cases.
- Medio - lateral oblique (MLO) view and other positions

3.7 Materials

3.7.1 Two full field digital mammography (FFDM) systems [14]

3.7.1.1 Manufacturer: Hologic (LORAD) Model: Selenia Molybdenum (Mo) and Rhodium (Rh) targets (Installed February 14, 2006).

The Selenia is a mode of the Lorad M-IV mammography system, which uses an image acquisition system including a digital image receptor. This receptor covers an area of 24 x 29 sq. cm as a direct– capture detector using an amorphous selenium photoconductor. The two focal spot sizes are 0.1mm for small nominal and 0.3mm for large nominal. The x-ray tube was Mo and Rh anodes, Mo and Rh filtration materials. At the acquisition workstation, x-ray exposure technique factor, can be selected as well as the automatic exposure control (AEC). Patient identification data can be added to acquire processes and display the digital images. Contrast and brightness are set automatically. The FFDM system is shown in Figure 3.1.

Figure 3.1 The FFDM Hologic, LORAD model Selenia system with Molybdenum and Rhodium targets.

3.7.1.2 Manufacturer: Hologic (LORAD) Model: Selenia Tungsten (W) and Rhodium (Rh) targets (Installed March 8, 2009).

The design of the Hologic Selenia full field digital mammography system is the use of amorphous selenium detector; the size of the image field is 24 cm x 29 cm. A moving grid system, using the Lorad HTC (high transmission cellular grid), is integrated into the detector assembly. The grid can be driven out of the image field if required. The Selenia is supplied with a range of compression plates. The Paddle system allows the field size to be automatically determined from the size of the compression plate in use. The two focal spot sizes are 0.1mm for small nominal and 0.3mm for large nominal. The x-ray tubes are W and Rh targets, with Ag and Rh filtration materials. Three user-selectable AEC operating modes are provided as auto-time (control of exposure duration), auto-kVp (control of exposure duration and automatic selection of optimum kVp) and auto filter (control of exposure duration, automatic selection of optimum kVp and filter). The FFDM system is shown in Figure 3.2.

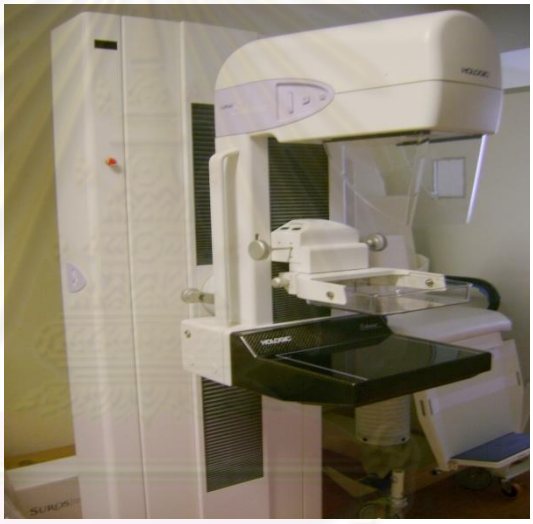


Figure 3.2 The FFDM Hologic, LORAD model Selenia system with Tungsten and Rhodium targets

3.7.2 Breast phantom

3.7.2.1 Gammex RMI model Gammex 156 [15]

The mammographic accreditation phantom RMI 156 is designed for the test of the performance of a mammographic system by a quantitative evaluation of the system's ability to image small structures similar to those found clinically. The mammographic phantom is made up of a wax block containing 16 various set of test objects, thick acrylic base, a tray for placement of the wax block. All of this together approximates a 4.5cm compressed breast. Five groups of simulated micro-calcification, six different size nylon fibers simulate fibrous structures, and five different size tumor-like masses are included in the wax insert. The Gammex RMI models Gammex 156 with the detail of inserts are shown in Figure 3.3.

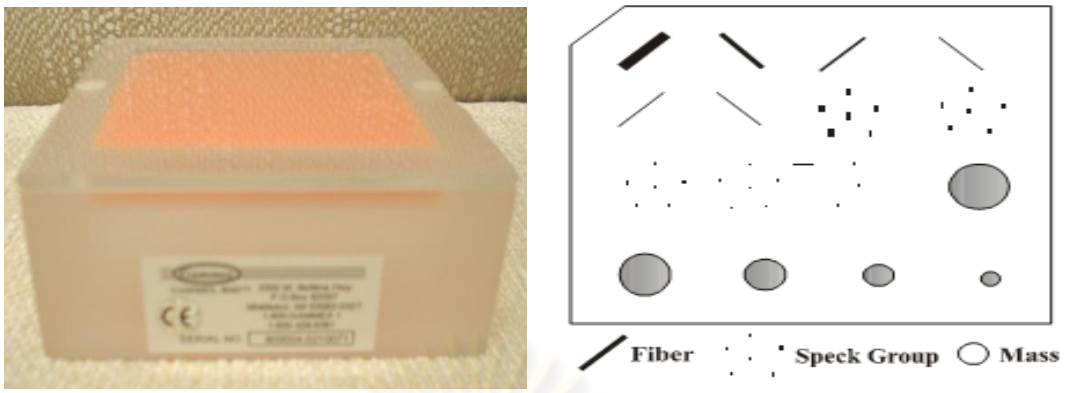


Figure 3.3 Gammex RMI model Gammex 156 breast phantom. (Gammex, 2002).

3.7.2.2 BR-12 or BR50/50 model 016A [16]

The phantom body is available in BR-12 or BR50/50 as shown in figure 3.4. It enables consistent, reproducible positioning of the bar pattern at 4.5 cm above the breast support plate at 1 cm from the chest wall, centered laterally as recommended by the American College of Radiologists. The bar pattern can also be positioned at a variety of heights for more thorough evaluations. The phantom includes a 30x hand-held microscope.

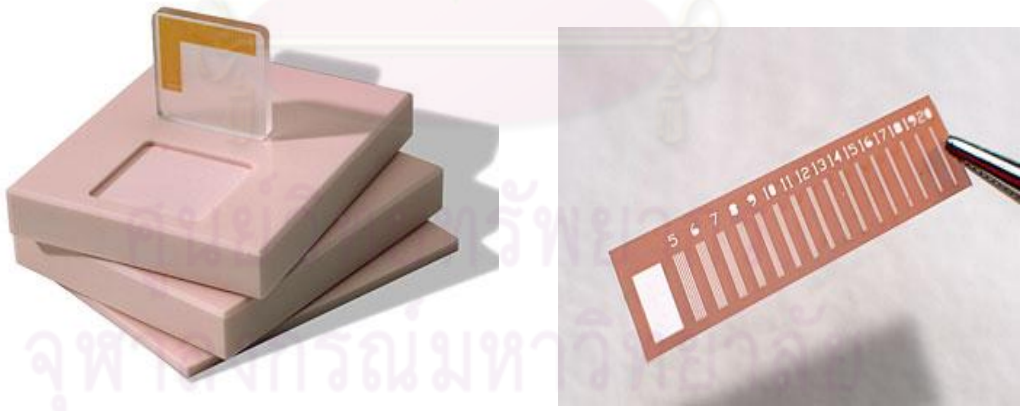


Figure 3.4 BR-12 or BR50/50 single exposure high contrast resolution breast phantom. (CIRS, 2005)

3.7.3 Radiation dosemeter [17]

The radiation dosemeter is a solid state detector manufactured by Unfors Model XI MAM as shown in figure 3.5. The detector could measure kVp, dose, dose rate, HVL, time and waveforms.

Figure 3.5 The Unfors XI solid state radiation dosemeter. (Unfors, 2005)

Solid state dosemeters are useful for four main reasons. First, their high density (800 to 4,000 times more atoms per c.c. than air) can lead to small sizes, e.g. in semiconducting devices. Further, electrical conductivity can be internally amplified, especially in CdS, by a factor of 10^2 or 10^3, so that currents 10^6 or 10^7 times greater than in gas ionization chambers can be obtained. Second, changes induced in solids by radiation may persist for long periods, enabling total dose to be estimated at a convenient time after the irradiation. Third, solid systems showing an obvious visible change are useful for measuring spatial distributions of dose. Fourth, higher dose-rates can be measured than by ionization chambers.

3.7.4 Picture archiving and communication system (PACS) and Diagnostic workstation 5 Megapixel (MP) monitor (Figure 3.6) [18]

The FFDM system is connected to PACS manufactured by AGFA and work station manufacturer EBM technologies. It consists of features and functions provide to read and perform diagnosis, navigate through images, and receive relevant patient information.

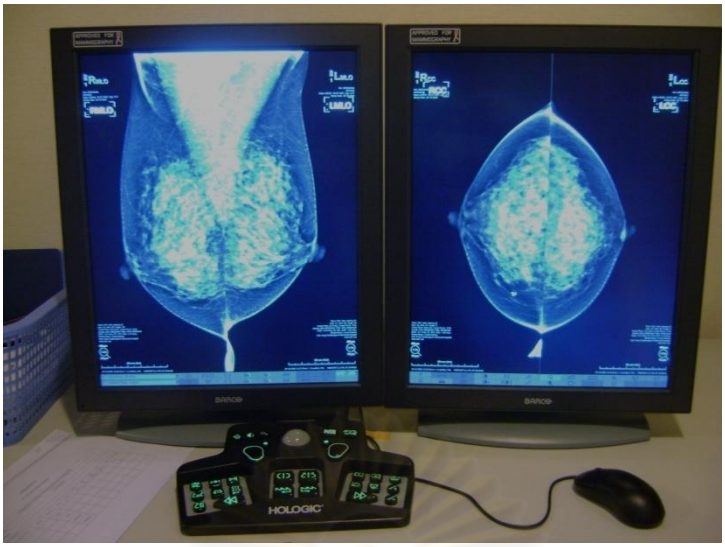


Figure 3.6 The picture archiving and communication system and diagnostic workstation 5 MP monitor

3.7.5 Mammographic report data from Hospital Information System (HIS) [19]

A hospital information system (HIS) or clinical information system (CIS) is a comprehensive, integrated information system designed to manage the administrative, financial and clinical aspects of a hospital. This encompasses paper-based information processing as well as data processing machines. It can be composed of one or a few software components with specialty-specific extensions as well as of a large variety of sub-systems in medical specialties (e.g. Laboratory Information System, Radiology Information System). CISs are sometimes separated from HISs in that the former concentrate on patient-related and clinical-state-related data (electronic patient record) whereas the latter keeps track of administrative issues. The distinction is not always clear and there is contradictory evidence against a consistent use of both terms.

3.7.6 Patients

Patient data was collected during the period April –Aug 2006 for molybdenum target FFDM system and April - Aug 2009 for tungsten target FFDM system.

3.8 Methods

3.8.1 Perform the quality control of both full-field digital mammography (FFDM) systems using the quality control protocol recommended by Lorad. (MQSA)

3.8.2 Verify average glandular dose (AGD) displayed on the monitor for both FFDM systems by measuring the breast entrance surface exposure (X_{ESE}) and converting to AGD (AGD1 obtained from molybdenum target and AGD2 obtained from tungsten target).

3.8.3 Record patient data from workstation (EBM- PACS), such as patient ID, age, CBT, CF, kVp, mAs, AGD and target-filter combination used, etc.

3.8.4 Compare AGD1 and AGD2 with similar breast thickness for two different target-filter combinations.

3.8.5 Determine the CNR data and percent contrast of both groups which had already met the eligible criteria from patient with pathology.

The contrast to noise ratio was determined by placing region of interest (ROI) of the same size on breast for signal, mass or calcification and background. The measured CNR and percent contrast was obtained by using equation (2) and (3) derived by IAEA [20]:

$$CNR = \frac{S_{AL} - S}{\sqrt{\frac{(\sigma_{AL}{}^2 + \sigma^2)}{2}}} \tag{2}$$

$$\%Contrast = \frac{mean(signal) - mean(background)}{mean(signal) + mean(background)} \times 100 \tag{3}$$

where

S_{AL} is the mean covered by aluminum (pixel value of signal)
S is the mean pixel value of background
σ_{AL} is the standard deviation for aluminum (signal)
σ is the standard deviation of background

3.8.6 Compare CNR and percent contrast between both groups.

3.9 Data collection

Patient ID, age, type of study, mAs, kVp, CBT, compression force, target-filter combination, and the AGD values were recorded (extracted from the image DICOM headers) in case record form.

3.10 Data analysis

3.10.1 The quality control data was analyzed using AAPM excel program with criteria for acceptable limits.

3.10.2 Verification of average glandular dose between the calculated values and the display on monitor.

3.10.3 Analyzed patient data between two systems (age, exposure factor, compressed breast thickness, compression force, breast composition and

patient dose) in terms of mean, median, ranges and standard deviation by the SPSS program.

- Compare AGD1 and AGD 2.
- Calculate CNR for breast with pathological disorders.
- Compare CNR 1 and CNR 2.

3.10.4 Data presentation, table and bar chart will be presented.

3.11 Outcome

3.10.1 Dependent variables: The AGD and CNR for 2 FFDM.

3.10.2 Independent variables: Procedure type, patient age, kVp, mAs, CBT, compression force and target-filter combination used.

3.12 Expected benefits and application

3.12.1 Guidance level (GL) for AGD in Thai female patients of 2 FFDM systems.

3.12.2 Range of technique parameters for two FFDM systems.

3.12.3 The awareness of radiologists and technologists concerns about AGD and the image quality on the patients from two FFDM systems at King Chulalongkorn Memorial Hospital.

3.12.4 The threshold level of contrast to noise ratio for each FFDM systems.

3.12.5 The advantage in the making decision on purchasing the new mammographic unit.

3.13 Ethical considerations

This research covers the comparison of average glandular dose and image quality in terms of CNR between two different target-filter combinations of FFDM systems. Review of data collection during the period April – July 2006 for Mo-target FFDM system and April – July 2009 for W-target FFDM system was performed, after the approval of the Ethics committee Faculty of Medicine Chulalongkorn University and the Director of King Chulalongkorn Memorial Hospital. Ethical principle in research involving human subjects was considered for confidentiality of patient, beneficence or non-maleficence, and non-bias in selection of subjects. The ethics was approved by the Ethics Committee of Faculty of Medicine, Chulalongkorn University in May 2009.

CHAPTER IV

RESULTS

4.1. Quality control

The results on quality control of LORAD Selenia FFDM two systems based on MQSA (Mammography Quality Standards Acts) for quality control performance are shown in Appendix B.

4.1.1 HVL determination

The percent difference of the HVL for Mo/Mo and W/Rh target/filter combination by measurement and calculation methods were compared as shown in Table 4.1 and, 4.2.

Table 4.1 The percent difference of HVL for Mo/Mo target/filter combination between the measured and calculated methods.

kVp	Measured HVL (mm Al)	Calculated HVL (mm Al)	Different HVL (mm Al)	Difference (%)
26	0.320	0.309	0.011	3.44
28	0.335	0.329	0.006	1.79
30	0.352	0.347	0.005	1.42
32	0.370	0.365	0.005	1.35
34	0.372	0.372	0.000	0.00

Table 4.2 The percent difference of HVL for W/Rh target/filter combination between the measured and calculated methods.

kVp	Measured HVL (mm Al)	Calculated HVL (mm Al)	Different HVL (mm Al)	Difference (%)
26	0.530	0.510	0.020	3.77
28	0.535	0.523	0.012	2.24
30	0.549	0.539	0.010	1.82
32	0.557	0.549	0.008	1.44
34	0.568	0.563	0.005	0.88

4.1.2 AGD verification

Verify the average glandular doses by calculate the average glandular dose, *D*G, to the standard breast from equation 4.

$$DG = C_{DG50,\,Ki,\,PMMA}\,sKi \qquad (4)$$

when;

DG is the average dose to the glandular tissues within the breast, known as the average glandular dose.

$C_{DG50,\ Ki,PMMA}$ is the conversion coefficient for the measured HVL and the standard breast of 50 mm thickness and 50% glandularity that is simulated by the 45 mm PMMA phantom. This coefficient converts the incident air kerma at the entrance surface of the PMMA phantom to the average glandular dose for the standard breast.

s is the values of factors for different mammographic target-filter combinations.

*K*i is the incident air kerma.

Table 4.3 Conversion coefficients $C_{DG50,\ Ki,\ PMMA}$ used to calculate the mean glandular dose to a 50 standard breast of 50% glandularity from the incident air kerma for a 45 mm PMMA phantom. [20]

HVL (mm Al)	$C_{DG50,Ki,PMMA}$ (mGy/mGy)
0.25	0.149
0.30	0.177
0.35	0.202
0.40	0.223
0.45	0.248
0.50	0.276
0.55	0.304
0.60	0.326
0.65	0.349

Table 4.4 Values of s factors for different mammographic target-filter combinations [20]

Target/filter combination	*s* factor
Mo/Mo	1.000
Mo/Rh	1.017
Rh/Rh	1.061
Rh/Al	1.044
W/Rh	1.042

Table 4.5 The percent difference of the AGD by using ACR phantom between the calculated and displayed on monitor for Mo/Mo target/filter combination [21].

kVp	mAs	Calculated AGD (mGy)	Displayed monitor (mGy)	Difference dose value (mGy)	Difference (%)
26	120	1.85	1.99	0.14	7.57
28	120	2.49	2.71	0.22	8.84
30	120	3.20	3.52	0.32	10.00
32	120	3.96	4.43	0.47	11.87

Table 4.6 The percent difference of the AGD by using ACR phantom between the calculated and displayed on monitor for Mo/Rh target/filter combination [21].

kVp	mAs	Calculated AGD (mGy)	Displayed monitor (mGy)	Difference dose value (mGy)	Difference (%)
26	120	1.83	2.16	0.33	18.03
28	120	2.39	2.81	0.42	17.57
30	120	3.05	3.51	0.46	15.08
32	120	3.71	4.26	0.55	14.82

Table 4.7 The percent difference of the AGD by using ACR phantom between the measured and calculated glandular dose for W/Rh target/filter combination.

kVp	mAs	Calculated AGD (mGy)	Displayed monitor (mGy)	Difference dose value (mGy)	Difference (%)
26	120	1.53	1.35	0.18	13.33
28	120	1.61	1.43	0.18	12.59
30	120	1.97	1.79	0.18	10.06
32	120	2.32	2.16	0.16	7.41

4.2 Patient information and factor affecting to average glandular dose

The average age of the patient was 50.44 years (range 40-60 years), S.D± 5.52, median of 50 years mode of 47 years.

The data selected from Mo-Mo target-filter (N=231) was compared to the W-Rh (N= 320) and Mo-Rh (N= 226) with W-Ag (N=105) as shown in Table 4.8.

Table 4.8 The groups of data selected with different target-filter combination.

Target-filter	Number of patient	Percent (%) selected
Mo-Mo	231	26.19
Mo-Rh	226	25.62
W-Rh	320	36.28
W-Ag	105	11.90
Total number of patients	882 data	100%

The mean of compressed breast thickness (CBT) was 6.04cm (range 2.8-9.1cm), S.D ±1.4, and values of high frequency CBT to selected was 5-5.9 cm, the distribution of CBT with number of patient from different target-filter combinations as shown in Figure 4.1.

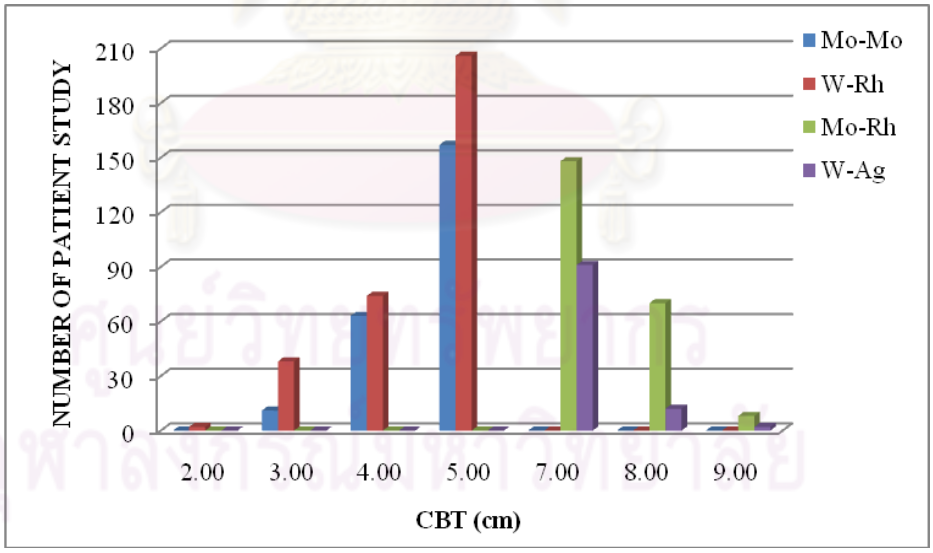


Figure 4.1 The distribution of CBT with number of patient study from different target-filter combinations.

The CBT for the Mo-Mo target filter system is up to 5.9 cm. For the CBT greater than 5.9 cm the Mo-Rh will be used. In the case of the second system, the maximum CBT for W-Rh is 6.9 cm, and then W-Ag will be selected at CBT over 6.9 cm. In order to compare two systems effectively, the patient data of CBT between 6.0-6.9 cm was excluded.

The studies involve mammographic procedures for screening and diagnosis at cranio - caudal (CC) view for both breast sides and only auto filter mode was used. The automatic exposure system selects all techniques based on CBT. The x-ray tube voltage and tube current ranged from 25 to 34 kVp, 31.6 to 229.4 mAs for Molybdenum target and 25 to 32 kVp, 59.7 to 339.2 mAs for Tungsten target. The ranges of kVp and mAs of data selected with different target-filter combination were shown in Table 4.9 and 4.10 respectively.

Table 4.9 The range of kVp from data selected with different target-filter combination

Target/Filter	Range of kVp	kVp Median	S.D
Mo-Mo	25-30	29	1.15
Mo-Rh	32-34	32	0.55
W-Rh	25-30	28	0.99
W-Ag	28-32	28	0.93

Table 4.10 The range of mAs from data selected with different target-filter combination

Target/Filter	Range of mAs	mAs Median	S.D
Mo-Mo	31.6-121.9	69.50	16.45
Mo-Rh	32.9-229.4	89.75	27.39
W-Rh	59.7-262.7	116.90	34.70
W-Ag	99.0-330.2	145.40	39.39

The compression force has relationships to compress breast thickness. The data show average compression force in mammography both cc view compared with CBT each system and percent of image study with compression force shown in Figure 4.2, 4.3, 4.4 respectively.

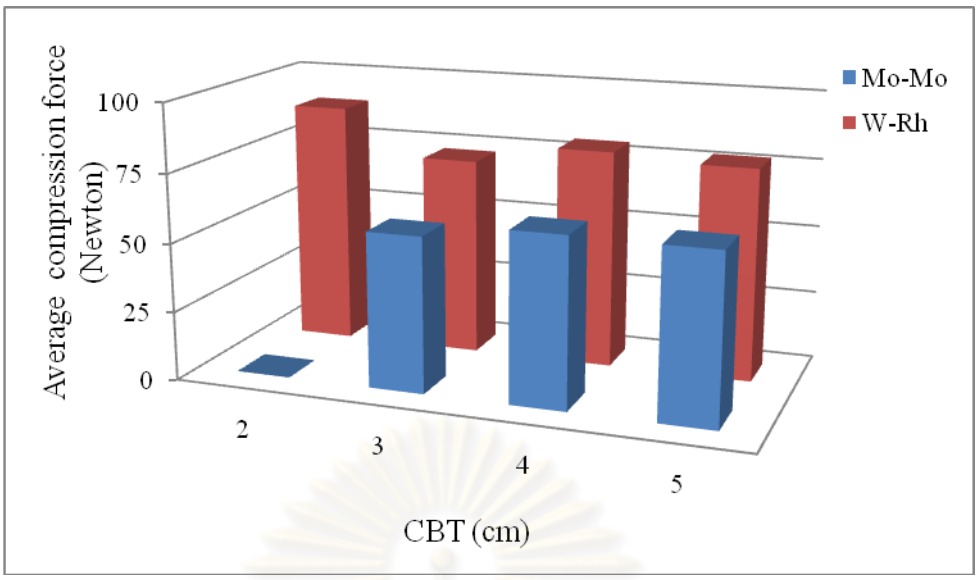


Figure 4.2 The diagram shows the average compression force (N) in mammography for both breasts at cc view against with the CBT (cm) between Mo-Mo and W-Rh target-filter combinations.

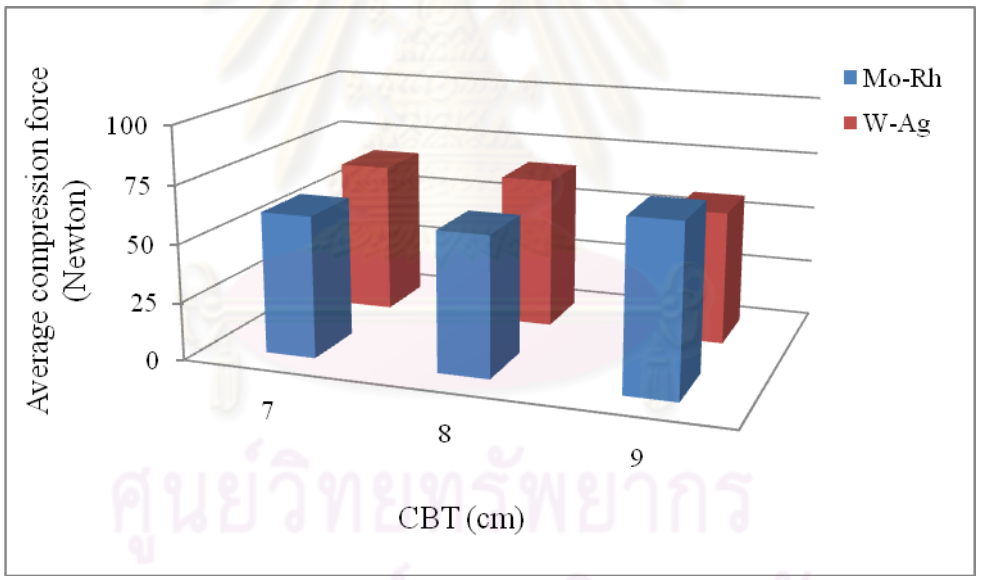


Figure 4.3 The average compression force in mammography both cc view (RCC and LCC) compared with CBT between Mo-Rh and W-Ag target-filter combinations.

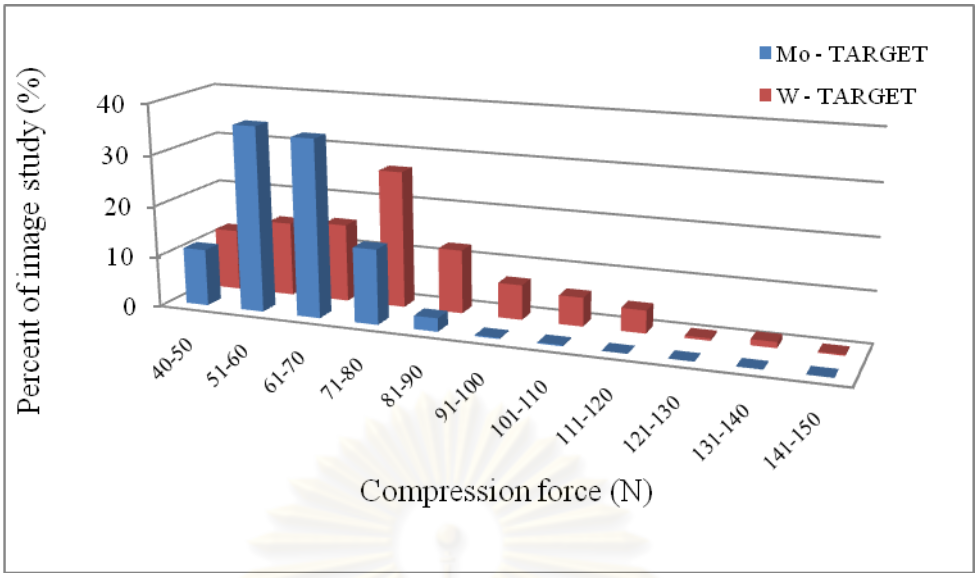


Figure 4.4 The percentage of image study with compression force between Molybdenum and Tungsten target

4.3 The average glandular dose

The result of average glandular dose (AGD) and the entrance surface air kerma (ESAK) between two systems of different target-filter combinations were summarized in Table 4.11 and 4.12. For the CBT of 28-59 mm, the AGD was 1.75 mGy for Mo-Mo and 1.43 mGy for W-Rh, the ESAK was 11.24 mGy for Mo-Mo and 5.25 mGy for W-Rh. When the CBT was 70-91 mm, the AGD was 2.01 mGy for Mo-Rh and 1.86 mGy for W-Ag. The ESAK was 14.77 mGy for Mo-Rh and 8.77 mGy for W-Ag are shown in Figure 4.5 and 4.6. For both size of the breast (big and small) the AGD and ESAK of Molybdenum target was higher than Tungsten target.

Summary of the technique factors, average glandular dose (AGD) and the entrance surface air kerma (ESAK) of both RCC and LCC views of different target-filter combination from the patient study are shown in Table 4.13 to 4.16

Table 4.11 The AGD and ESAK when used different tube-target combinations.

CBT (mm)	Target-Filter	AGD (mGy)	Third Quartile of AGD	ESAK (mGy)	Third Quartile of ESAK	% Reduction of AGD for target-filter combinations	% Reduction of ESAK for target-filter combinations
28-59	Mo-Mo	1.75	2.0	11.24	13.15	18.29%	53.29%
	W-Rh	1.43	1.65	5.25	6.29		
70-91	Mo-Rh	2.01	2.37	14.77	17.48	7.46%	40.62%
	W-Ag	1.86	2.04	8.77	9.69		

Table 4.12 The AGD and ESAK between two systems.

System (target)	AGD (mGy)	Third Quartile of AGD	ESAK (mGy)	Third Quartile of ESAK	% Reduction of AGD for different target	% Reduction of ESAK for different target
1 (Molybdenum)	1.88	2.17	12.99	15.3	18.08%	52.88%
2 (Tungsten)	1.54	1.76	6.12	7.44		

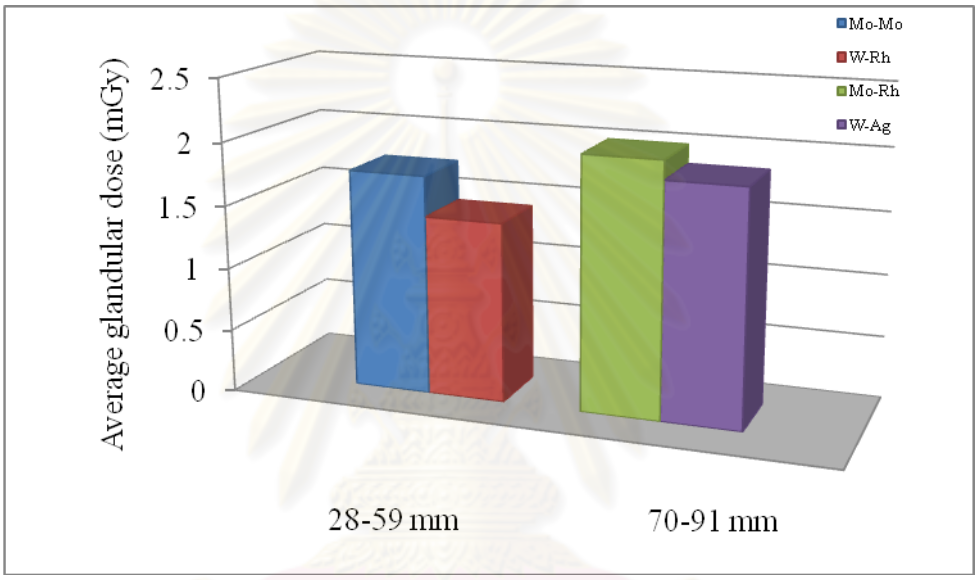


Figure 4.5 The average glandular dose (AGD) at different compressed breast thickness of 28-59 and 70-91 mm of different tube-target combinations

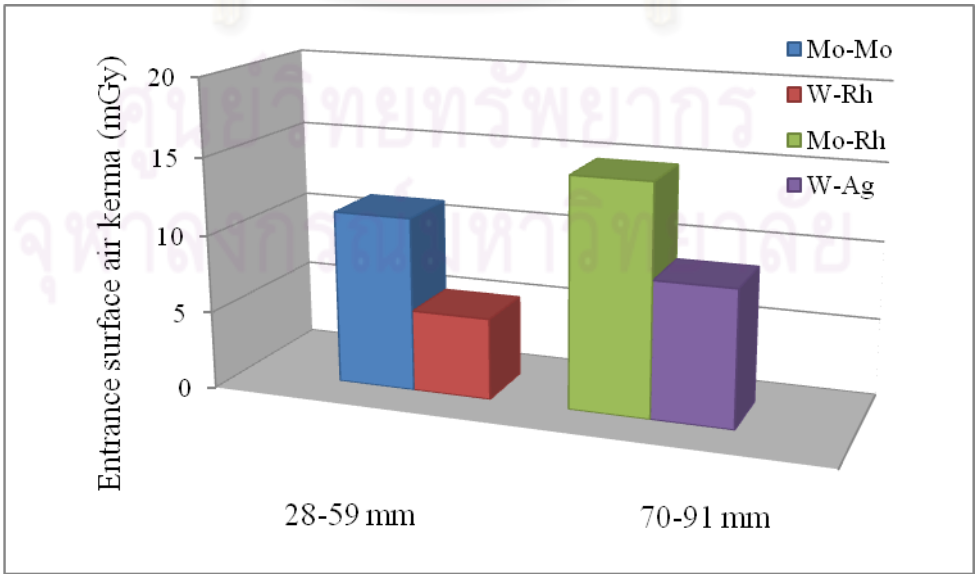


Figure 4.6 The entrance surface air kerma (ESAK) when used different tube-target combinations

The AGD was reduced to 18.29% when changed from Mo-Mo to W-Rh and 7.46% when changed from Mo-Rh to W-Ag target filters. The ESAK was reduced to 53.29% when Mo-Mo was changed to W-Rh and 40.62% when Mo-Rh was changed to W-Ag target- filter combinations are shown in Figure 4.7 and 4.8.

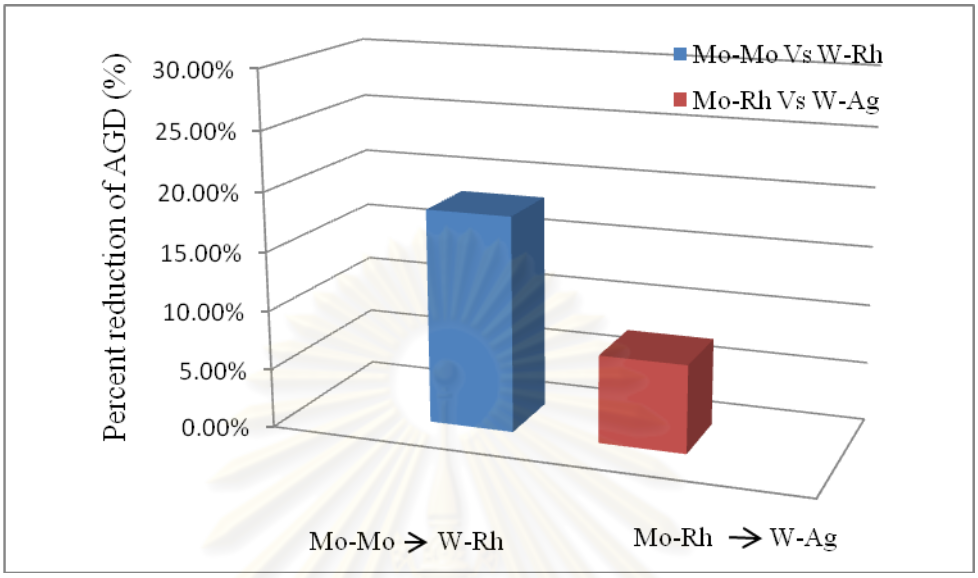


Figure 4.7 Percent reduction of AGD when Mo-Mo was changed to W-Rh and Mo-Rh to W-Ag target- filter combinations.

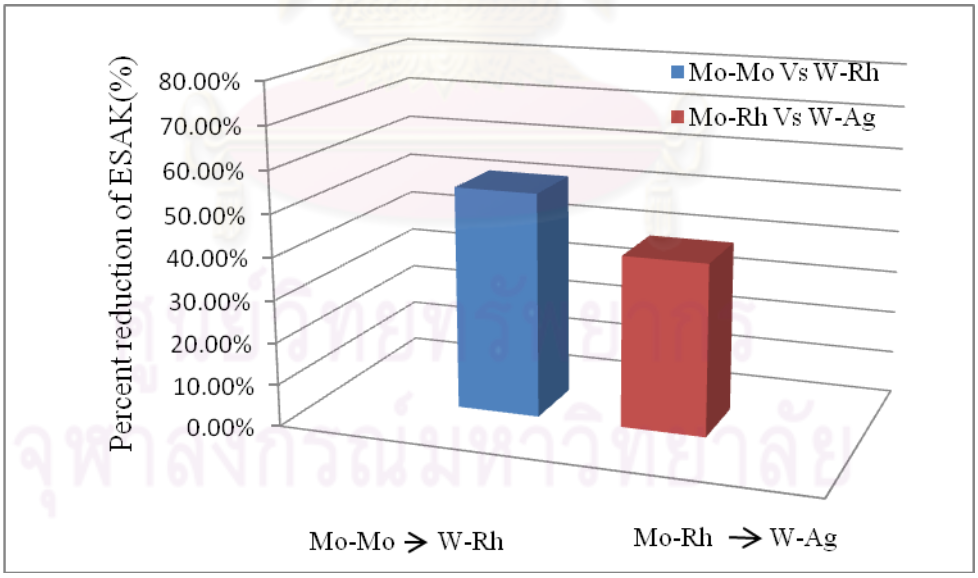


Figure 4.8 Percent reduction of ESAK when Mo-Mo was changed to W-Rh and Mo-Rh to W-Ag target- filter combinations

The AGD is increasing when the CBT increased shown in Figure 4.9 and 4.10

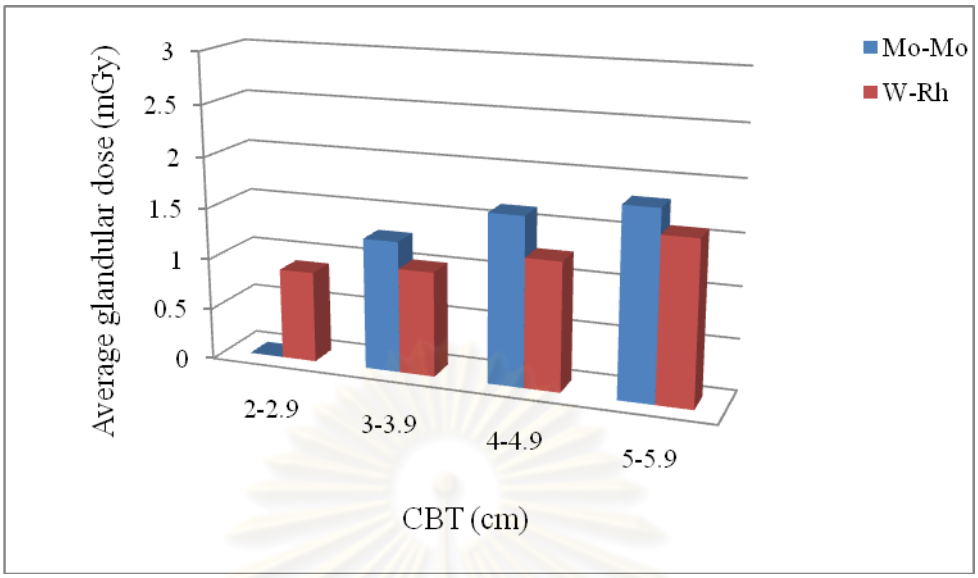


Figure 4.9 The average glandular dose with compressed breast thickness from 2.0-5.9 mm between Mo-Mo and W-Rh target- filter combinations

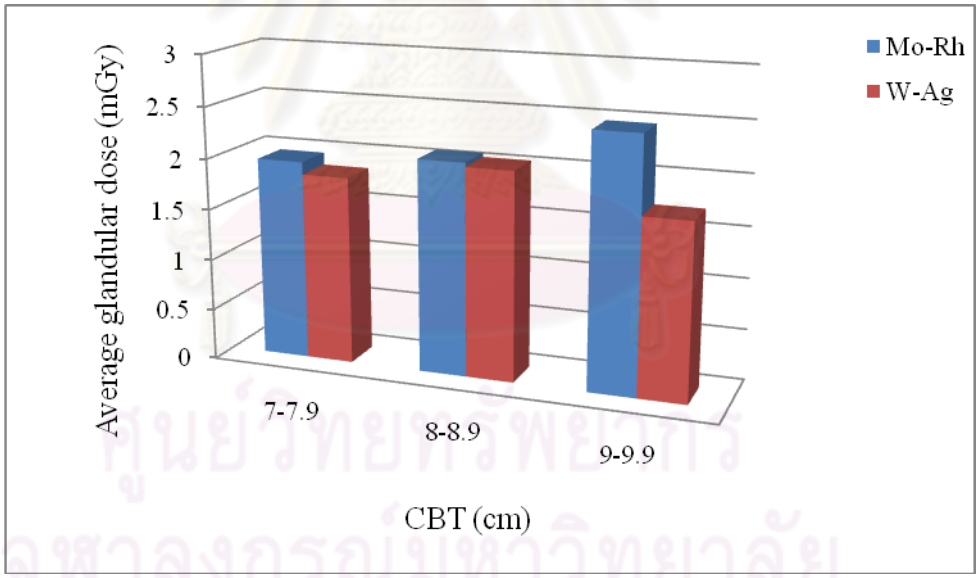


Figure 4.10 The average glandular dose with compressed breast thickness from 7.0-9.9 cm between Mo- Rh and W- Ag target- filter combinations

The average glandular dose (AGD) per view with grid should be less than 3.0 mGy as recommended by the American College of Radiologist (ACR). The results of percent of image study from data are selected. 1.36 % of the AGD per image higher than 3.0 mGy is shown in Figure 4.11 and 4.12

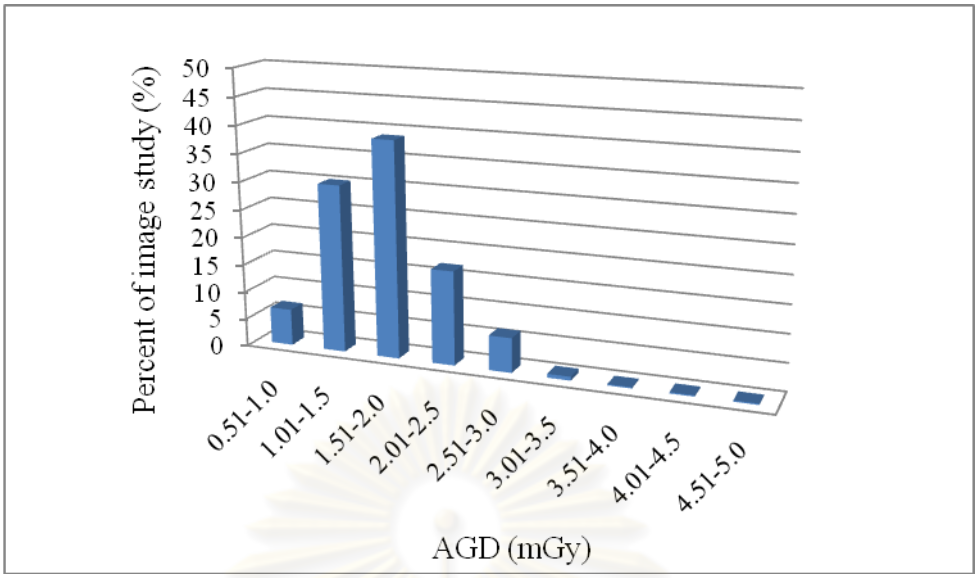


Figure 4.11 The percentage of image study with the average glandular dose

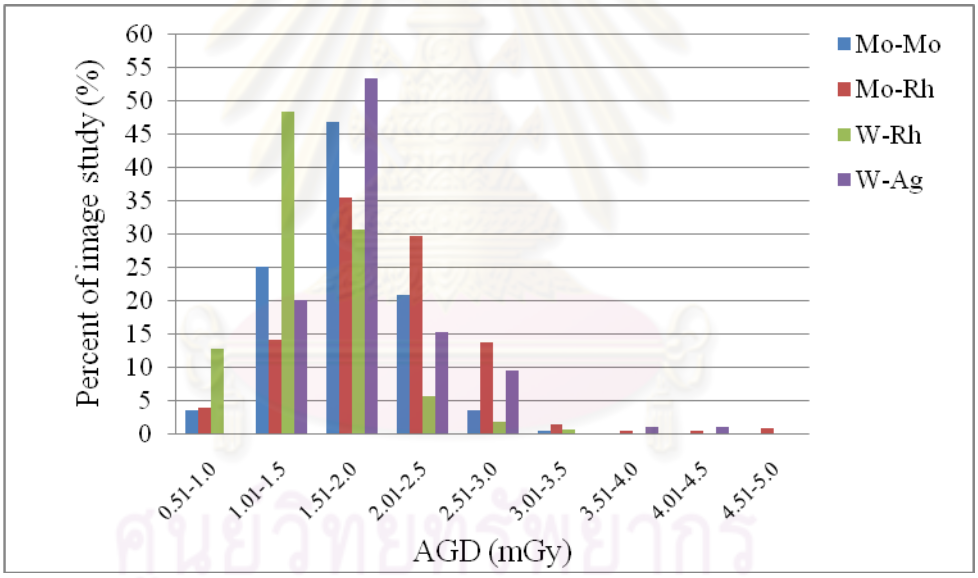


Figure 4.12 The percentage of image study with the average glandular dose from different target-filter combination

Table 4.13 The summary of the technique factors of both CC views RCC and LCC view of Mo/Mo and Mo/Rh target-filter combination from the patient study

View (image)	Target/Filter Combination (% Frequency)	Compress Breast Thickness (cm)	Compression Force (N)	kVp	mAs
		Mean(Range) ±SD	Mean(Range) ±SD	Mean(Range) ±SD	Mean(Range) ±SD
BOTH CC (RCC+LCC) (457)	Mo/Mo (50.55) Mo/Rh (49.45)	6.42 (3.3-9.1) ±1.41	61.36 (43.5-106.8) ±9.14	30.59 (25-34) ±1.99	81.4 (31.6-229.4) ±25.13
RCC (231)	Mo/Mo (48.48) Mo/Rh (51.52)	6.5 (3.4-9.1) ±1.42	62.23(43.5-106.8) ±10.08	30.69 (25-34) ±1.98	83.12(32.9-199.7) ±24.4
LCC (226)	Mo/Mo (52.65) Mo/Rh (47.35)	6.34 (3.3-9.1) ±1.4	60.46(44.5-84.55) ±7.99	30.5 (25-34) ±2.0	79.65 (31.6-229.4) ±25.79

Table 4.14 The summary of the technique factors of both CC views RCC and LCC views of W/Rh and W/Ag target-filter combination from the patient study

View (image)	Target/Filter Combination (% Frequency)	Compress Breast Thickness (cm)	Compression Force (N)	kVp	mAs
		Mean(Range) ±SD	Mean(Range) ±SD	Mean(Range) ±SD	Mean(Range) ±SD
BOTH CC (RCC+LCC) (425)	W/Rh (75.29) W/Ag (24.71)	5.62 (2.8-9.1) ±1.02	74.57 (44.5-142.3) ±20.13	28.19 (25-32) ±1.02	130.11 (59.7-330.2) ±39.22
RCC (201)	W/Rh (74.63) W/Ag (25.37)	5.62 (2.8-8.9) ±1.3	74.8(44.5-142.3) ±19.53	28.14 (25-31) ±1.03	131.06(59.7-270) ±38.84
LCC (224)	W/Rh (75.89) W/Ag (24.11)	5.63 (3.1-9.1) ±1.26	74.36(44.5-137.9) ±20.7	28.23 (26-32) ±1.02	129.27 (63.6-330.2) ±39.64

Table 4.15 The AGD and ESAK of RCC and LCC views of Molybdenum target from the patient study

View (image)	AGD per image (mGy) Mean(Range)±SD	Third Quartile	ESAK per image (mGy) Mean(Range) ±SD	Third Quartile
RCC (231)	1.91(0.73-4.55) ±0.51	2.2	13.3(5.27-38.1) ±4.29	15.35
LCC (226)	1.85(0.72-4.89) ±0.55	2.13	12.67(4.55-39.7) ±4.43	15.15

Table 4.16 The AGD and ESAK of RCC and LCC views of Tungsten target from the patient study

View (image)	AGD per image (mGy) Mean(Range)±SD	Third Quartile	ESAK per image (mGy) Mean(Range) ±SD	Third Quartile
RCC (201)	1.54(0.67-3.74) ±0.46	1.75	6.15(1.98-19.1) ±2.54	7.27
LCC (224)	1.53(0.73-4.06) ±0.47	1.76	6.09(2.1-18.8) ±2.46	7.46

4.4 Contrast to noise ratio (CNR)

The image quality results as the contrast to noise ratio (CNR) were studied from the patients with pathological disorders (calcification and mass). The data is shown as the percentage of patient underwent breast screening of 40.7% negative and 59.3% breast pathology as shown in figure 4.13. The groups of breast pathology were divided into two groups of calcification and mass. Percent of image study with breast pathology from different target for the calcification of molybdenum target was 36.18% and 14.47% for mass, 36.84% for calcification of tungsten and 12.5% for mass as shown in Table 4.16 .

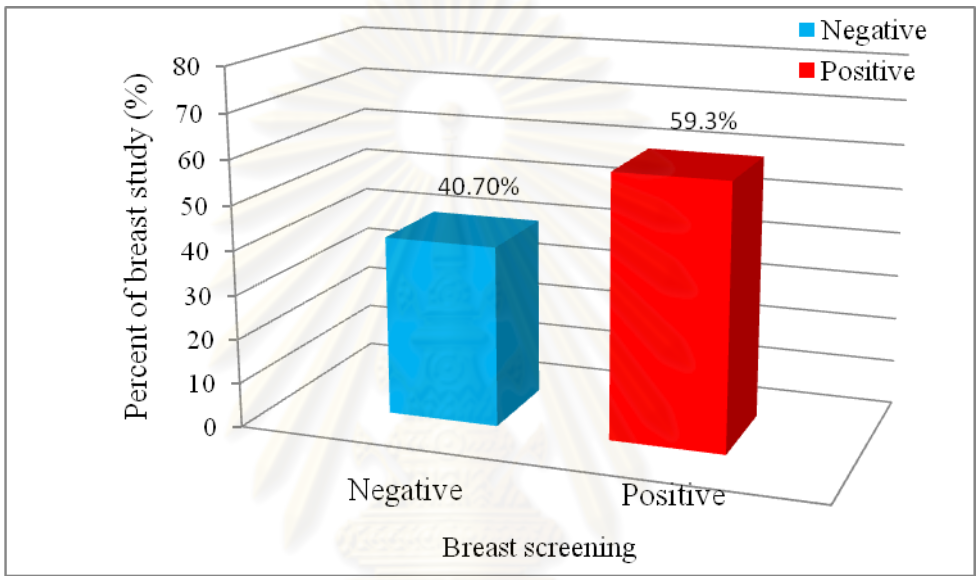


Figure 4.13 Percent negative and positive of patient study underwent breast screening was available form report of Radiologist classify by ACR BIRAD.

Table 4.17 Percent of image study with breast pathology from different target

Breast pathology	Percent of patient with breast pathology (%) from different target	
	Molybdenum	Tungsten
Calcification	36.18	36.84
Mass	14.47	12.5

The CNR and percent contrast (%) of calcification and mass with of Molybdenum and Tungsten target from the patient with pathology were shown in terms of mean, range, SD of the data between two systems of different target-filter combination are shown in Table 4.17 and 4.18

Table 4.18 The CNR and percent contrast of calcification and mass of Molybdenum and Tungsten targets from the patient with pathology.

Breast pathology	Target	N	CNR Mean(Range) ±SD	% Contrast Mean(Range) ±SD
Calcification	Molybdenum	110	0.94(0.04-3.62) ±0.68	9.85(0.37-40.83) ±6.7
	Tungsten	112	1.20(0.04-4.34) ±0.9	14.17(0.58-44.63) ±8.88
Mass	Molybdenum	44	1.38(0.15-5.92) ±1.19	11.41(1.47-30.76) ±7.4
	Tungsten	38	1.06(0.22-3.62) ±0.79	13.48(3.08-31.74) ±8.15

The mean CNR for calcification detection from Mo/Mo target/filters combination is 0.86 ±0.66 minimal contrast detectable is 0.04, the percent contrast is 9.52±7.35 compare with mean CNR of W/Rh is 1.05±0.75 minimal contrast detectable is 0.04 which is equal to Mo/Mo target/filters combination, the percent contrast is 12.44 ±7.74, but percent minimal contrast detectable is 0.58 higher than Mo/Mo is 0.37.

For the range of CBT 70-91 mm Mo/Rh mean CNR is 1.04±0.69 minimal contrast detectable is 0.21, the percent contrast is 10.49±5.79 compare with mean CNR of W/Ag is 1.59±1.14 minimal contrast detectable is 0.12 the percent contrast is 16.82 ±10.86.

Table 4.19 The CNR and percent contrast of calcification and mass with different Target-filter combination from the patient with pathology (from data selected).

Breast pathology	Target-filter combination	N	CNR Mean(Range) ±SD	% Contrast Mean(Range) ±SD
Calcification	Mo-Mo	62	0.86(0.04-3.62) ±0.66	9.52(0.37-40.83) ±7.35
	W-Rh	81	1.05(0.04-2.99) ±0.75	12.44(0.58-40.99) ±7.74
	Mo-Rh	48	1.04(0.21-2.99) ±0.69	10.49(2.25-26.45) ±5.79
	W-Ag	31	1.59(0.12-4.34) ±1.14	16.82(1.91-44.63) ±10.86
Mass	Mo-Mo	21	1.36(0.21-5.92) ±1.35	10.5(2.31-29.47) ±7.75
	W-Rh	38	1.06(0.22-3.62) ±0.79	13.84(3.08-31.74) ±8.15
	Mo-Rh	23	1.4(0.15-4.87) ±1.05	11.68(1.47-30.76) ±7.19

The mean CNR for mass detection from Mo/Mo target/filters combination is 1.36±1.35 minimal contrast detectable is 0.21, the percent contrast is 10.5±7.75 compare with mean CNR of W/Rh is 1.06±0.79 minimal contrast detectable is 0.22, the percent contrast is 13.84 ± 8.15. The mean CNR for mass from Mo/Rh target/filters combination is 1.4±1.05 minimal contrast detectable is 0.15, the percent contrast is 11.68±7.19. The CNR for mass detection from the W/Ag is not available as there was no patient data.

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Discussion

5.1.1 Quality control of the digital mammography system.

The maximal percent difference of HVL for Mo/Mo target/filter combination for the measured and the calculated methods is 3.44% at 26 kVp. For the W/Rh target/filter combination the maximum difference is 3.77% at 26 kVp. The percentages of difference decreases with increasing tube voltage.

The AGD was verified by using ACR standard breast phantom at each kVp 120 mAs between the calculated and display on monitor methods, for molybdenum target the calculated method is lower than display on monitor. For Mo/Mo target/filter combination the maximum of different value is 0.47 mGy at 32 kVp, the percent difference is 11.87%. For Mo/Rh target/filter combination the maximum of different value is 0.55 mGy at 32 kVp, and the maximum of percent difference is 18.03% at 26 kVp. For W/Rh target/filter combination the calculated method is higher than displayed on monitor the maximum of different value is 0.18 mGy at 28 and 30 kVp and the maximum of percent difference at 28 kVp is 12.59%.

The difference between calculated method and display on monitor of average glandular dose occurred from the uncertainties of dose measurement by radiation dosemeter and other scenario, such as conversion coefficient, s factors and HVL measurement. The uncertainties of Unfors dosemeter are approximately 10% for mammogram. Those were published by IAEA [20].

5.1.2 Patient information and factor affecting to average glandular dose

5.1.2.1 Patient age.

The ranges of patient age was 40 to 60 years, with the mean of 50.44 ± 5.52 years and mode of 47 years. The ranges of data recommended by IAEA [20] were suitable and benefit for patient underwent to breast screening.

The patient age is affecting the average glandular dose, for the age of less than 49 years; almost of the breast composition is dense breast and high CBT more than the age of over 49 years, thus the patients whose age are less than 49 got high radiation dose than the age of greater 49 years old.

5.1.2.2 Compressed breast thickness (CBT)

The mean of compressed breast thickness (CBT) for CC views was 6.04±1.4 cm (range 2.8-9.1), which is higher than mean CBT of other institute such as Michigan medical center mean CBT was 4.4 cm reported by MA Helvie et.al [22]. At Buddhachinaraj Hospital, Phitsanulok study in the lower region of northern Thailand, the mean CBT was 3.74cm [23], M.A. Whall and P.J. Roberts [24] reported the mean CBT of 5.5cm.

The average glandular dose in breast screening mammography increases with compressed breast thickness as detail in Table 4.11.

5.1.2.3 Compression force (CF)

The average (range) compression force from two systems was 67.72 Newton (43.5-142.3), for CC view which was close to P Pewluang et.al, Khon Kaen University, Thailand, [25] about mammographic technique, the mean compression force was 78.58 Newton (range 44.4 - 186.48 Newton) and lower than the United States, guidelines. The compression force in clinical use ranges from 102 - 150 Newton with a mean of 126 Newton [26].The CF in Michigan medical center for the CC view was 30-170 Newton (mean, 86 Newton).The CF for both maximum and minimum are regulated by the MQSA [27]. All dedicated mammography units have compression devices with an automatic and Newton (25-40 lb).

The compression force in mammography is an accepted technique for improving image quality and reducing dose, but excessive compression can cause pain and other undesirable effects.

In our study, many patients have breast pain with a high compression force, the technologist reduced compression force in women whose breasts are particularly sensitive, resulting in the increased CBT and AGD to patients. As the compressed breast thickness (CBT) resulted by the CF, the AGD is influenced by the CF directly.

Thus, the CF depends on many factors such as, breast composition, cooperation and tolerance of patients; the technician must try to explain to patient for the increasing CF to reduce CBT and AGD.

5.1.2.4 Technique factors (kVp and mAs)

The kVp accuracy was within ±5% for the measured and the indicated or selected kVp. The range of kVp from data selected was 25 to 30 for Mo/Mo target/filter combination, and 32 to 34 for Mo/Rh target/filter combination. For W/Rh target/filter combination, the kVp was 25 to 30 and 28 to 32 for W/Ag target/filter combination. AEC mode was selected for all cases with Auto-Filter. The x-ray tube voltage increases with increasing breast thickness and the filter was changed. The increasing CBT resulted in increasing AGD, therefore the kVp is directly affecting AGD.

The range of mAs for Mo/Mo target/filter combination was 31.6-121.9 (S.D.±16.45), Mo/Rh target/filter combination from 32.9-229.4 (S.D.±27.39). For W/Rh target/filter combination the mAs was 59.7-262.7 (S.D.±34.7) and W/Ag target/filter combination from 99.0-330.2 (S.D.±39.39). The mAs was selected as breast composition and compressed breast thickness with AEC technique. Therefore, mAs is affecting AGD.

Mode setting technique factors for mammography of two FFDM systems consist of AEC such as, Auto-time, Auto-kV, Auto-filter, TEC and manual technique. In routine study, the Auto-filter technique produces the good image quality and low radiation dose to patient as suggested by manufacturer. In fact, all modes should be used for screening mammogram to optimize the image quality and the dose to patients.

5.1.3 The average glandular dose (AGD)

The mean AGD for CC views with molybdenum target system is 1.88 mGy and mean ESAK is 12.99 mGy which is close to Chevalier et.al [28], of 1.80 mGy. For mean AGD of tungsten target system of 1.54 mGy and mean ESAK is 6.12 mGy which is close to J.F. Florian et.al [29], of 1.51 mGy. The percent reduction of AGD and ESAK when changing target from molybdenum to tungsten is 18.08% and 52.88% respectively as detail in Table 4.12.

The AGD for Mo-Mo comparing with W-Rh decreased from 1.75 mGy to 1.43 mGy or 18.29% and the ESAK decreased 53.29% when changing target from molybdenum to tungsten target system. The AGD was 2.01 mGy for Mo/Rh and 1.86 mGy for W/Ag target/filter combination respectively. The AGD decreased 7.46% and ESAK decreased 40.62% as detail in Table 4.11. Varjonen et.al reported the AGD reduction from 40 % to 60 % when changing from molybdenum to tungsten target filter in phantom study of different thickness but similar composition.

To calculate a p value, the unpaired, or "independent samples" t-test is used when two separate independent and identically distributed samples are obtained, one from each of the two populations being compared. The unpaired t-test is significantly different of AGD when change from molybdenum to tungsten target system showing statistically significant difference ($p < 0.05$) for different target/filter combination between two systems as shown in Table 5.3 to 5.5.

Table 5.1 The independent sample test to compare AGD between molybdenum and tungsten target systems for CC view.

Independent Sample Test (Unpaired t test)

Anode target	N	Mean	S.D.	t	Sig.
Molybdenum	457	1.88	0.53	10.108	<0.0001
Tungsten	425	1.54	0.47		

Table 5.2 The independent sample test to compare AGD between Mo/Mo and W/Rh target/filter combinations.

Independent Sample Test (Unpaired t test)

Target/filter	N	Mean	S.D.	t	Sig.
Mo/Mo	231	1.75	0.42	8.808	<0.0001
W/Rh	320	1.43	0.41		

Table 5.3 The independent sample test to compare AGD between Mo/Rh and W/Ag target/filter combinations.

Independent Sample Test (Unpaired t test)

Target/filter	N	Mean	S.D.	t	Sig.
Mo/Rh	226	2.01	0.59	2.291	0.023
W/Ag	105	1.86	0.48		

In this study the mean AGD per image for CC view from molybdenum target is 1.88 mGy (Third quartile 2.17) and tungsten target is 1.54 mGy (Third quartile 1.76) which is lower than dose reference level (DRL) of ACR recommended that the average glandular dose is 3 mGy (with grid) per view. Only 1.36 % of this study showed the AGD of higher than the limit of 3 mGy. Different target-filter combinations for mammogram affected the patient dose for both ESD and ESAK. More mammographic study in Thai for the country should be continued to optimize the average glandular dose and image quality.

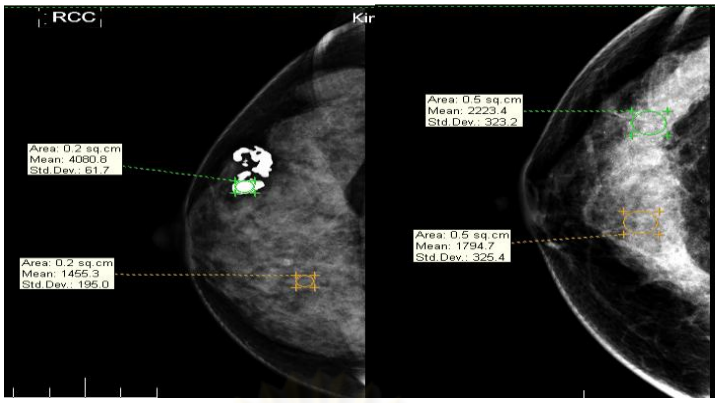
5.1.4 Contrast to noise ratio (CNR)

The image quality in mammogram was determined in terms of the contrast to noise ratio with breast pathology of two categories of calcifications (macro, micro) and masses closely reported by Fischmann et.al [30]. They compared the image quality with the detection of calcifications and masses between film-screen mammography and full-field digital mammography to detect the breast pathology in mammography. The auto – filter was used on both systems for standard acquisition parameters.

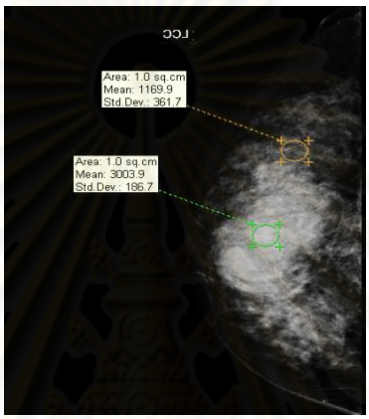
ROI drawn must be equal size of lesion. The errors in calculating CNR may be occurred from the exceed ROI from the lesion especially in mass resulting in the decreasing value of CNR. The method of drawing ROI in the lesion is shown in Figure 5.1

For the calcification detection, the range of CBT 28-59 mm Mo/Mo is high efficiency no significantly different ($p > 0.05$) in calcify lesion detection when compared to W/Rh as shown in Table 5.4. The range of CBT 70-91 mm W/Ag is significantly different in calcifies lesion detection when compared to Mo/Rh as shown in Table 5.5.

For mass detection, the range of CBT 28-59 mm Mo/Mo is high efficiency no significantly different ($p > 0.05$) in mass lesion detection when compared to W/Rh as shown in Table 5.6. For the W/Ag is not available to compared with Mo-Rh because of there was no patient data.



(A) (B)



(C)

Figure 5.1 The method of CNR measurement with breast pathology
(A) Macro-calcification
(B) Micro-calcification (specks group)
(C) Mass

The technical quality of the study is of fundamental importance in this process. Many factors affect image quality and breast dose in patient. For this study the CNR and the percent contrast are the parameters for the image quality to improve the detection of mass and calcification.

The use of tungsten target can show higher CNR and percent contrast in breast with calcification as in Table 4.17. For mass detection, molybdenum target shows higher contrast than tungsten target but percent contrast was little less than tungsten target.

However, the image quality cannot be compared between two systems quantitatively as different demographic data, of two groups of patient.

Table 5.4 The independent sample test to compare CNR with breast calcification detection between Mo/Mo and W/Rh target/filter combinations.

Independent Sample Test (Unpaired t test)

Target/filter	N	Mean	S.D.	t	Sig.
Mo/Mo	62	0.86	0.66	1.565	0.119
W/Rh	81	1.05	0.75		

Table 5.5 The independent sample test to compare CNR with breast calcification detection between Mo/Rh and W/Ag target/filter combinations.

Independent Sample Test (Unpaired t test)

Target/filter	N	Mean	S.D.	t	Sig.
Mo/Rh	48	1.04	0.69	2.663	0.009
W/Ag	31	1.59	1.14		

Table 5.6 The independent sample test to compare CNR with breast mass detection between Mo/Mo and W/Rh target/filter combinations.

Independent Sample Test (Unpaired t test)

Target/filter	N	Mean	S.D.	t	Sig.
Mo/Mo	21	1.36	1.35	1.071	0.288
W/Rh	38	1.06	0.79		

5.2 Conclusion

The comparison of AGD and image quality between two different target-filter combinations of FFDM systems were performed at King Chulalongkorn Memorial Hospital. The average glandular dose (AGD) per CC view with grid was 1.88 mGy from molybdenum target and 1.54 mGy for tungsten target. For the CBT of 28-59 mm, the AGD and ESAK for Mo-Mo was 1.75 and 11.24 mGy and 1.43 and 5.25 mGy for W-Rh. The AGD and ESAK was reduced to 18.29% and 53.29% respectively, when changed from Mo-Mo to W-Rh. For CBT of 70-91 mm, the AGD and ESAK for Mo-Rh was 2.01 and 14.77 mGy and 1.86 and 8.77 mGy for W-Ag. The AGD and ESAK were reduced to7.46% and 40.62% respectively, when changed from Mo-Rh to W-Ag.

The different target-filter combinations affected on average glandular dose and the entrance surface air kerma significantly for the p-value of less than 0.05. In clinical mammography, higher energy beam spectra obtained using W/Rh anode/filter combinations may significantly contribute to lower AGD compared to Mo/Mo, Mo/Rh.

The image quality in terms of CNR for calcification detection at CBT 28-59 mm, Mo-Mo compared to W/Rh was 0.86 (range 0.04-3.62) and 1.05 (range 0.04-2.99), minimal contrast detectable is 0.04 for both target-filters, the percent contrast was 9.52(0.37-40.83) and 12.44 (0.58-40.99) respectively, but the percent contrast minimal detectable was 0.37, lower than W/Rh of 0.58, thus the range of CBT 28-59 mm Mo/Mo is no significantly different ($p > 0.05$) in calcify lesion detection when compared to W/Rh. For CBT 70-91 mm, Mo/Rh compared to W/Ag, the mean CNR was 1.04 (0.21-2.99) and 1.59 (0.12-4.34), minimal contrast detectable was 0.21 and 0.12 respectively, the percent contrast was 10.49 (2.25-26.45) and 16.82 (1.91-44.63), thus the range of CBT 70-91 mm W/Ag is significantly different in calcify lesion detection when compared to Mo/Rh. The mean CNR for mass detection from CBT 28-59 mm, Mo-Mo compared to W/Rh was 1.36 (0.21-5.92) and 1.06 (0.22-3.62), minimal contrast detectable was 0.21 and 0.22 respectively, the percent contrast was 10.5 (2.31-29.47) and 13.84 (3.08-31.74), thus the range of CBT 28-59 mm Mo/Mo was no significantly different ($p > 0.05$) in mass lesion detection when compared to W/Rh. The mean CNR for mass from CBT 70-91 mm, Mo/Rh was 1.4 (0.15-4.87), the minimal contrast detectable was 0.15, the percent contrast was 11.68 (1.47-30.76). There was no patient data for W/Ag target.

With careful analysis and consideration of physic principles, high-quality mammograms can be obtained at a reasonable low dose. However, to achieve the lowest dose may degrade the performance of mammography in the detection and characterization of breast lesions.

5.3 Benefits and Recommendations

It is recommended that the quality control of mammography system must be performed before the use of AEC.

The average glandular dose should be recorded for normal routine study of four views per examination. Total AGD should not exceed 3 mGy per view with grid and 1 mGy without grid as recommended by ACR. AGD should be studied when additional views per exam and repeat study for follow up in one year were requested.

The radiologists, technologists and medical staff should increase the awareness and concerns about AGD and the image quality on the patients.

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APPENDICES

APPENDIX A

CASE RECORD FORM

Case No.	Examination		Date			
	MMG procedures		/ /			
Age (Yrs.)			Positioning			
			R-CC		L-CC	
	screening	diagnosis	Yes	No	Yes	No

Inclusion criteria	R-CC	L-CC	Accepted data	
			Yes	No
1. CBT				
2. CF				
3. kVp				
4. mAs				
5. AGD				
1. Target-filter combination used				
• Mo/Mo				
• Mo/Rh				
• W/Rh				
• W/Ag				
2. Imaging report data				
• Normal				
• Calcification				
• Fatty breast				
• Focal dense breast				
• Other pathology disorders				

Exclusion criteria	Accepted data	
	Yes	No
1. Implant breast		
2. Breast conservation surgery		
3. Non AEC cases.		
4. Medio - lateral oblique (MLO) view and others positions		
COMPLETE DATA	Yes	No

APPENDIX B

QUALITY CONTROL OF MAMMOGRAPHIC SYSTEM

(Room No.1: Mo-Target)

Quality Control Activities for the Medical Physicist

Location: Mammography Unit Vongvanitch 2 (King Chulalongkorn Memorial Hospital)
Equipment: Hologic Lorad Model Selenia (Mo-Target)
Model Number: ASY- 00689
Date: 17 Mar 2009

1. Mammography Unit Assembly Evaluation

Objective

To ensure good and safe working conditions of all interlocks, mechanical detents and safety switches and to ensure mechanical integrity of the x- ray tube and digital image receptor assembly.

Regulatory action levels

The Lorad Selenia FFDM System shall provide:

- an override of automatic decompression to allow maintenance of compression.
- a continuous display of the override status.
- a manual emergency compression release that can be activated in the event of power or automatic release failure.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Results

Table I. The mammographic unit assembly evaluated for the period 2009-2010

1. Free-standing unit is mechanically stable	Pass
2. All moving parts move smoothly, without obstruction to motion	Pass
3. All locks and detents work properly	Pass
4. Image receptor holder assembly is free from vibrations	Pass
5. Image receptor slides smoothly into holder assembly	Pass
6. Image receptor is held securely by assembly in any orientation	Pass
7. Compressed breast thickness scale accurate to +/-0.5cm, reproducible +/-2 mm	Pass
8. Patient or operator is not exposed to sharp or rough edges, or other hazards	Pass
9. Operator technique control charts are posted	Pass
10. Operator protected during exposure by adequate radiation shielding	Pass
11. All indicator lights working properly	Pass
12. Auto decompression can be overridden to maintain compression (status displayed)	Pass
13. Manual emergency compression release can be activated in the event of power failure	Pass

2. Collimation Assessment

Objective

To assure that the collimator assembly perform in the following way:
- The x-ray field coincides with the light field.
- The x-ray field is aligned with the image receptor.
- The compression paddle is aligned with the image receptor.

X-ray field to light field coincidence

Regulatory action levels

The total misalignment (sum of the misalignment on opposite sides) must be within 2% of SID.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Source-to-image receptor distance (SID): 66 cm

Results

Table II. Deviation between X-ray field and light field

Target material	Mo	Mo	Mo	Mo
Collimator (cm)	24x29	18x24(L)	18x24(C)	18x24(R)
Left edge deviation	0.1	0.7	0.2	0.6
Right edge deviation	0.2	0.1	0.1	0.3
Sum of right and left edge deviations	0.3	0.8	0.3	0.9
Sum as % of SID	0.45	1.21	0.45	1.36
Anterior edge deviation	0.8	0.6	0.7	0.6
Chest edge deviation	0.2	0.2	0.2	0.2
Sum of anterior & chest edge deviations	1.0	0.8	0.9	0.8
Sum as % of SID	1.51	1.21	1.36	1.21

X-ray field to image receptor alignment

Regulatory action levels

The x-ray field at the plane of the image receptor may extend beyond any edge of the image receptor, but it must not extend by more than 2% of the SID at the chest wall side.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Results

Table III. Deviation between X-ray field & edges of the image receptor

Collimator (cm)	24x29	18x24(L)	18x24(C)	18x24(R)
Left edge deviation	0.2	0.7	0.2	0.6
% of SID (retain sign)	0.3	1.06	0.3	0.91
Right edge deviation	0.2	0.1	0.1	0.2
% of SID (retain sign)	0.3	0.15	0.15	0.3
Anterior edge deviation	0.7	0.6	0.7	0.6
% of SID (retain sign)	1.06	0.91	1.06	0.91
Chest edge deviation	0.2	0.2	0.2	0.2
% of SID (retain sign)	0.3	0.3	0.3	0.3

Compression paddle to image receptor alignment

Regulatory action levels

The anterior edge of the compression paddle should be aligned just beyond the chest wall edge of the image receptor so that it does not appear in the mammogram. In addition, the anterior edge of the compression paddle should not extend beyond the chest wall edge of the image receptor by more than 1% of the SID.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Results

Table IV. Alignment of chest wall edges of compression paddle and image receptor.

Paddle (cm)	24x29	18x24(Fast)
Difference between paddle edge and image receptor	0.3%	0.3%

3. Artifact Evaluation

Objective

To assess the degree and source of artifacts visualized in mammograms or phantom images. This procedure allows the source of artifacts to be isolated to x-ray equipment, DICOM printer, or film processor.

Regulatory action levels

Artifacts that may interfere with image interpretation must be eliminated before performing clinical imaging.

Corrective action

Consult with a radiologist for assistance in evaluating whether artifacts may interfere with image interpretation. A qualified service engineer must eliminate any digital detector artifacts that may be clinically objectionable.

The acrylic attenuation block provided by the manufacturer and used for detector calibration must be replaced if it has permanent artifacts that may impact detector calibration.

The recommendations and corrective actions listed in the 1999 ACR Mammography Quality Control Manual must be followed for DICOM printer and film processor artifacts.

Type of attenuator: Acrylic
Thickness of attenuator: 4.0 cm
kVp setting: 28 kVp (Auto-time)

Results

Table V. Artifact evaluation from acrylic phantom

Image receptor size	24x29	24x29	18x24	18x24
Target/Filter	Mo/Mo	Mo/Rh	Mo/Mo	Mo/Rh
Focal spot	large	large	small	small
Acceptable?	O.K.	O.K.	O.K.	O.K.

Table VI. Artifact evaluation from DICOM printer.

Image Size	18x24	24x29
Acceptable?	O.K.	O.K.

4. kVp Accuracy and Reproducibility

Objective

To assure that the selected kVp is accurate within limits and reproducible between exposures.

Regulatory action levels

The kVp shall be accurate within ±5% of the indicated or selected kVp at:
- The lowest clinical kVp that can be measured by a kVp test device.
- The 28 kVp.
- The highest available clinical kVp.

At 28 kVp, the coefficient of variation of the kVp shall be equal to or less than 0.02.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

kVp meter used: Unfors model; XI

Results

Table VII. kVp Accuracy and Reproducibility

Nominal kVp setting	21	22	23	24	25	26	27	28	29	30	31
Focal spot	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
mAs setting	30	30	30	30	30	30	30	30	30	30	30
Measured kVp values:											
kVp1	19.74	21.45	22.71	23.85	24.94	26.0	27.07	28.16	29.26	30.41	31.43
kVp2	19.76	21.42	22.68	23.85	24.95	25.95	27.06	28.18	29.25	30.37	31.51
kVp3	19.81	21.44	22.66	23.85	24.93	26.02	27.15	28.27	29.25	30.36	31.49
kVp4	19.76	21.38	22.77	23.87	24.91	25.98	27.12	28.22	29.25	30.38	31.44
Mean kVp	19.77	21.42	22.71	23.86	24.93	25.98	27.1	28.21	29.25	30.38	31.47
Standard Deviation	0.03	0.03	0.04	0.009	0.02	0.03	0.04	0.04	0.004	0.02	0.03
Mean kVp- Nominal kVp	1.23	0.58	0.3	0.14	0.07	0.01	0.1	0.21	0.25	0.38	0.47
0.05 x Nominal kVp	1.05	1.10	1.15	1.2	1.25	1.3	1.35	1.4	1.45	1.5	1.55
Coefficient of Variation (SD/ Mean kVp)	0.001	0.001	0.002	0	0.001	0.001	0.001	0.001	0	0.001	0.001
%Error	-5.86	-2.64	-1.26	-0.58	-0.28	-0.08	0.37	0.75	0.86	1.27	1.52

Results

Table VIII. kVp Accuracy and Reproducibility (cont.)

Nominal kVp setting	32	33	34	35
Focal spot	0.3	0.3	0.3	0.3
mAs setting	30	30	30	30
Measured kVp values: kVp1	32.57	33.63	34.70	35.68
kVp2	32.57	33.49	34.65	35.65
kVp3	32.57	33.62	34.67	35.52
kVp4	32.57	33.61	34.56	35.56
Mean kVp	32.52	33.59	34.65	35.60
Standard Deviation	0.06	0.06	0.05	0.07
Mean kVp- Nominal kVp	0.52	0.59	0.64	0.6
0.05 x Nominal kVp	1.6	1.65	1.7	1.75
Coefficient of Variation (SD/ Mean kVp)	0.002	0.002	0.002	0.002
%Error	1.63	1.79	1.91	1.71

5. Beam Quality Assessment- HVL Measurement

Objective

To assure that the half-value layer (HVL) of the x-ray beam is adequate to minimize patient dose without being too excessive to compromise image contrast.

Regulatory action levels

For operating kVp range of less than 50, the measured HVL shall be greater than (kVp/100)+0.03(in mm Al).

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Dosimetry System Used: Unfors Model XI.

Results

Table IX. Beam Quality Assessment- HVL Measurement

Nominal kVp Setting:	26	28	30	32	34
Target/Filter	Mo/Mo	Mo/Mo	Mo/Mo	Mo/Mo	Mo/Mo
Paddle in place	Yes	Yes	Yes	Yes	Yes
mAs Setting	30	30	30	30	30
Exposure Measurements:(mGy)					
No Aluminum Filtration, E_{oa}	2.556	3.246	3.987	4.8	5.908
0.2 mm of added Aluminum, $E_{0.2}$	1.610	2.091	2.625	3.206	3.996
0.3 mm of added Aluminum, $E_{0.3}$	1.305	1.712	2.173	2.669	3.332
0.4 mm of added Aluminum, $E_{0.4}$	1.075	1.429	1.814	2.269	2.819
0.5 mm of added Aluminum, $E_{0.5}$	0.889	1.193	1.532	1.897	2.424
0.6 mm of added Aluminum, $E_{0.6}$	0.753	1.009	1.312	1.629	2.065
No Aluminum Filtration, E_{ob}	2.566	3.250	3.996	4.805	5.911
Calculation					
$E_o = (E_{oa} + E_{ob})/2$	2.561	3.248	3.992	4.803	5.909
$E_{1/2} = E_o/2$	1.281	1.624	1.996	2.401	2.955
Exposure greater than $E_{1/2}$: E_a	1.305	1.712	2.173	2.669	3.332
Al thickness at E_a:t_a	0.3	0.3	0.3	0.3	0.3
Exposure less than $E_{1/2}$: E_b	1.075	1.429	1.814	2.269	2.819
Al thickness at E_b:t_b	0.4	0.4	0.4	0.4	0.4
Calculated HVL(mmAl)	0.31	0.32	0.34	0.37	0.37
Minimum allowed	0.29	0.31	0.33	0.35	0.37

$$\text{HVL} = \frac{t_b \ln[2E_a/E_o] - t_a \ln[2E_b/E_o]}{\ln[E_a/E_b]}$$

6. System Limiting Spatial Resolution

Objective

To evaluate imaging performance, using the system limiting spatial resolution as a performance indicator that may be easily measured in the field

Regulatory action levels

The system limiting spatial resolution must be greater than 7c/mm (lp/mm) when the bars are at 45° to the anode-cathode axis.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken before any further examinations are performed.

X-ray Tube Manufacturer: Hologic Lorad
Model Number: ASY- 00689

Results

Table X. Spatial resolution for nominal focal spot size

Nominal focal spot size (mm)	0.3
Target material	Mo
Nominal kVp setting	28
mAs	100
Limiting resolution in cycles per mm	10

7. Automatic Exposure Control (AEC) Function Performance

Objective

To assess the performance of the automatic exposure control (AEC) function and to maintain consistency in detector signal level for a range of breast thickness and all applicable imaging modes.

To evaluate the Exposure Compensation Function of the AEC.

Regulatory action levels

The pixel value of each individual image corresponding to a breast thickness between 2 and 8 cm at any operating mode shall not very more than 10% of the mean pixel value recorded from all tested breast thickness and operating mode.

Corrective action

If the reproducibility criteria are not met, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

If the average glandular dose criteria are not met, a qualified service engineer must correct the problem before using the system for clinical imaging.

AEC sensor position: 2
Exposure Compensation Step: 0

Results

Table XI. Performance capability for AEC

Contact Imaging, LFS with Grid								
Phantom thickness	AEC Mode	Filter	kVp	mAs	Exp Comp Step	Pixel Value	CNR Correction Factor	Corrected Pixel Value*
2cm	Auto-Filter	Mo	25	44.2	0	650.4	1	600.4
4.1cm	"	Mo	27	98.4	0	612.3	1	562.3
6.1cm	"	Mo	30	169	0	620.4	1	570.4
8.1cm	"	Mo	30	270.2	0	720.6	1.5	447.07
Magnification Imaging, SFS without Grid								
4.1cm	Auto-Filter	Mo	27	68	0	625.9	1	575.9
Mean Pixel Value		Pixel Value Range			Allowed Pixel Value			
551.21		447.07 to 600.4			494.1 to 603.9			

*Pixel Value = (ROI mean – DC Offset (50))/ CNR Correction Factor

Table XII. Exposure compensation

Contact Imaging, LFS with Grid							
Phantom thickness	AEC Mode	Exp Comp	Pixel Value*	Ratio**	Allowed Ratio*		
4cm	Auto-Filter	-3	307.9	0.546	0.50	to	0.61
4cm	"	-2	390.4	0.693	0.63	to	0.77
4cm	"	-1	476.6	0.846	0.77	to	0.94
4cm	"	0	560.9	0.996			
4cm	"	0	567.7	1.008			
4cm	"	0	560.3	0.995			
4cm	"	+1	647.3	1.149	1.04	to	1.27
4cm	"	+2	725.8	1.289	1.17	to	1.43
4cm	"	+3	808.8	1.436	1.31	to	1.60
4cm	"	+4	881.1	1.565	1.44	to	1.76

*Pixel Value = ROI mean – DC Offset (50)
**Pixel Value at given step divided by mean pixel value at step 0

8. Breast Entrance Exposure, Average Glandular Dose, and AEC Reproducibility

Objective

To measure the typical entrance exposure and calculate the corresponding glandular dose for an average patient with approximately 4.5 cm compressed breast thickness of 50% adipose, 50% glandular tissue composition; to assess the reproducibility of the automatic exposure control (AEC).

Regulatory action levels

The coefficient of variation for air kerma shall not exceed 0.05.

The average glandular dose delivered during the single cranio-caudal view of an FDA accepted phantom simulating a standard breast shall not exceed 3.0 mGy (0.3 rad) per exposure. The dose shall be determined with technique factor and conditions used clinically for a standard breast.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken before any further examinations are performed.

Results

Imaging mode:	Digital
Field Restriction:	24x29 cm
SID (cm):	66
Source-detector distance (cm):	62
Source-bucky distance (cm):	66
Dosimeter used:	Unfors

Table XIII. Breast entrance exposure**.**

Breast thickness(cm)	4.5	
Phantom	ACR	
Nominal kVp setting	30	
Target material	Mo	
Filter	Mo	
AEC Mode	Auto-Filter	
AEC Position	2	
Exp. Compensation step	0	
Measured HVL (mm Al)	0.362	
Exposure	mGy	mAs
Exposure#1	1.501	49.5
Exposure#2	1.509	49.7
Exposure#3	1.493	49.5
Exposure#4	1.507	48.7
Mean values	1.502	49.25
Standard deviation (SD)	0.007	0.443
Coefficient of variation(CV)	0.000	0.147

9. Radiation Output Rate

Objective

To measure the radiation output rate of the system.

Regulatory action levels

The system shall be capable of producing a minimum output of:

- 2.0 mGy air kerma per second (230mR per second) when operating at 28 kVp in the standard mammography (Mo/Mo) mode at any SID where the system is designed to operate and when measured by a ionization chamber with its center located 4.5cm above the breast support surface with the compression paddle in place between the source and the ionization chamber.

The system shall be capable of maintaining the required minimum output rate averaged over a 3.0 second period.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Results

SID (cm): 66
Source-detector distance (cm): 59.5
Dosimeter used: Unfors Model XI

Table XIV. Radiation output rate

3 sec, 4.5cm above breast support	kVp	Anode	Filter	SID (cm)	mAs	Air Kerma (mGy)
	28	Mo	Mo	66	320	3.812
	28	Mo	Mo	66	320	3.804

Dose rate (mGy/sec) = Exp Rate (mR/s) x 0.00873 mGy/mR

10. Phantom Image Quality Evaluation

Objective

To assess the quality and consistency of the mammographic image

Regulatory action levels

The phantom image, evaluated on digital hardcopy film, shall achieve at least a minimum score of 5.0 fibers, 4.0 speck groups, and 4.0 masses, using a phantom accepted by the accreditation body for screen-film mammography. There may be shall fluctuations in scoring of the fibers and masses due to phantom variations. If the fiber score is 4.5 and or the mass score is 3.5, then examine the SNR and high contrast resolution of the system.

If both those exceed recommended criteria, then a total score of 4.5 fibers, 4.0 speck and 3.5 masses is acceptable

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified.

If the source is identified as the digital detector, corrective action shall be taken before any further examinations are performed.

If the source is a diagnostic device, imaging on the digital detector can be continued; the diagnostic device shall be corrected before used for mammographic image interpretation.

Phantom used: ACR Phantom GAMMEX (RMI) Model: 156

Results

Table XV. Phantom image quality evaluation

	Current Image	Comments
Date	18 Mar 2009	
kVp setting	28	
mAs setting	96.1	
Number of fibers seen	5	
Number of speck groups seen	4	
Number of masses seen	4	

11. Signal-To-Noise and contrast-To-Noise Measurements

Objective

To assure consistency of the digital image receptor by evaluating the signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) of the digital image receptor

Regulatory action levels

The SNR shall be equal to or greater than 40.

The CNR shall remain within ±15% of the CNR determined as part of the LORAD Selenia FFDM System Evaluation which was completed after installation.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken before any further examinations are performed.

Results

Table XVI. Signal-To-Noise and contrast-To-Noise Measurements

	Current	Last	Comment
Date	18 Mar 2009		
Selected kVp	28	28	
Selected mAs	95	95	
Selected Filter	Mo	Mo	
Background Mean Value	625	614.6	
Background standard deviation	9.5	9.4	
Signal-To-Noise Ratio	62.5	62.04	
Mean Value on top of disk	515.3	515.6	
Standard deviation on top of disk	9.2	9.1	
Contrast-To-Noise ratio	11.55	10.53	
% CNR difference		8.83%	

12. Viewbox Luminance and Room Illuminance

Objective

To assure that the viewboxes used for mammographic image interpretation or quality control meet or exceed minimum levels.

To assure that the room illuminance levels are below prescribed levels.

To assure that viewing conditions have been optimized.

Regulatory action levels

Appropriate viewbox luminance levels and room illuminance is necessary so that subtle features can be perceived by the radiologist.

Corrective action

None.

Results

Table XVII. Viewbox Luminance and Room Illuminance

	Radiologist's Viewboxes	
	Reading Area 1	Reading Area 2
Viewbox luminance(cd/m^2)	1675	1645
Illuminance on monitor surface(lux)	65.46	69.20
Illuminance seen by observer(lux)	56.67	55.56
Dirt and marks	N	N
Color difference	N	N
Luminance difference	N	N
Uniformity	Y	Y
Functioning Masks	N	N

13. Diagnostic Review Workstation QC

Objective

To assure consistency of the brightness, contrast and image presentation of the radiologist's diagnostic review workstation

Regulatory action levels

The computer software analyzes the results and provides an indication if the monitors met the pre-programmed control limits.

Corrective action

If the software indicates that the control limits are exceeded, the problem shall be corrected before any clinical or phantom images are read on the workstation.

Results

Table XVIII. Diagnostic Review Workstation QC
Photometer Serial Number; 143473

	Left Monitor	Right Monitor	Comment
Monitor Serial Number	1890033200	1890024831	
White Level Performance	313.9 cd/m^2	311.9 cd/m^2	
Black Level Performance*	0.66 cd/m^2	0.65 cd/m^2	

***** Black Level Performance and Uniformity Performance only apply to CRT displays. If LCD displays are used, these checks are not performed and "N/A" shall be entered.

14. Detector Ghosting (Optional)

Objective

To assure that the level of detector ghosting does not interfere with image quality.

Regulatory action levels

The measured Ghost Image Factor must be within ±0.3 for consecutive images acquired within approximately 1 minute of each other.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken before any further examinations are performed.

Results

Table XIX. Test Exposure

	Filter	kVp	Exposure Step	mAs
Exposure 1	Mo	28	0	98.6
Exposure 2	Mo	28	0	102.2

Region 1 Factor	Region 2	Region 3	Ghost Image
623.5	610.2	610.2	0

QUALITY CONTROL OF MAMMOGRAPHIC SYSTEM

(Room No.2: W-Target)

Quality Control Activities for the Medical Physicist

Location: Mammography Unit Vongvanitch 2 (King Chulalongkorn Memorial Hospital)
Equipment: Hologic Lorad Model Selenia (W-Target)
Model Number: 4-000-0014
Date: 18 Mar 2009

1. Mammography Unit Assembly Evaluation

Objective

To ensure good and safe working conditions of all interlocks, mechanical detents and safety switches and to ensure mechanical integrity of the x- ray tube and digital image receptor assembly.

Regulatory action levels

The Lorad Selenia FFDM System shall provide:

- an override of automatic decompression to allow maintenance of compression.
- a continuous display of the override status.
- a manual emergency compression release that can be activated in the event of power or automatic release failure.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Results

Table XX. The mammographic unit assembly evaluated for the period 2009-2010

1. Free-standing unit is mechanically stable	Pass
2. All moving parts move smoothly, without obstruction to motion	Pass
3. All locks and detents work properly	Pass
4. Image receptor holder assembly is free from vibrations	Pass
5. Image receptor slides smoothly into holder assembly	Pass
6. Image receptor is held securely by assembly in any orientation	Pass
7. Compressed breast thickness scale accurate to +/-0.5cm, reproducible +/-2 mm	Pass
8. Patient or operator is not exposed to sharp or rough edges, or other hazards	Pass
9. Operator technique control charts are posted	Pass
10. Operator protected during exposure by adequate radiation shielding	Pass
11.All indicator lights working properly	Pass
12. Auto decompression can be overridden to maintain compression (status displayed)	Pass
13. Manual emergency compression release can be activated in the event power failure	Pass

2. Collimation Assessment

Objective

To assure that the collimator assembly perform in the following way:
- The x-ray field coincides with the light field.
- The x-ray field is aligned with the image receptor.
- The compression paddle is aligned with the image receptor.

X-ray field to light field coincidence

Regulatory action levels

The total misalignment (sum of the misalignment on opposite sides) must be within 2% of SID.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Source-to-image receptor distance (SID): 66 cm

Results

Table XXI. Deviation between X-ray field and light field

Target material	W	W	W	W
Collimator (cm)	24x29	18x24(L)	18x24(C)	18x24(R)
Left edge deviation	0.1	0.7	0.2	0.6
Right edge deviation	0.2	0.1	0.1	0.6
Sum of right and left edge deviations	0.3	0.8	0.3	1.2
Sum as % of SID	0.45	1.21	0.45	1.8
Anterior edge deviation	1.0	0.8	0.7	0.7
Chest edge deviation	0.2	0.2	0.2	0.2
Sum of anterior & chest edge deviations	1.2	1.0	0.9	0.9
Sum as % of SID	1.81	1.51	1.36	1.36

X-ray field to image receptor alignment

Regulatory action levels

The x-ray field at the plane of the image receptor may extend beyond any edge of the image receptor, but it must not extend by more than 2% of the SID at the chest wall side.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Results

Table XXII. Deviation between X-ray field & edges of the image receptor

Collimator (cm)	24x29	18x24(L)	18x24(C)	18x24(R)
Left edge deviation	0.1	0.7	0.2	0.6
% of SID (retain sign)	0.15	1.06	0.3	0.91
Right edge deviation	0.2	0.1	0.1	0.6
% of SID (retain sign)	0.3	0.15	0.15	0.91
Anterior edge deviation	1.0	0.8	0.7	0.7
% of SID (retain sign)	1.52	1.21	1.26	1.26
Chest edge deviation	0.2	0.2	0.2	0.2
% of SID (retain sign)	0.3	0.3	0.3	0.3

Compression paddle to image receptor alignment

Regulatory action levels

The anterior edge of the compression paddle should be aligned just beyond the chest wall edge of the image receptor so that it does not appear in the mammogram.

In addition, the anterior edge of the compression paddle should not extend beyond the chest wall edge of the image receptor by more than 1% of the SID.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Results

Table XXIII. Alignment of chest wall edges of compression paddle and image receptor.

Paddle (cm)	24x29	18x24(Fast)
Difference between paddle edge and image receptor	0.3%	0.3%

3. Artifact Evaluation

Objective

To assess the degree and source of artifacts visualized in mammograms or phantom images. This procedure allows the source of artifacts to be isolated to x-ray equipment, DICOM printer, or film processor.

Regulatory action levels

Artifacts that may interfere with image interpretation must be eliminated before performing clinical imaging.

Corrective action

Consult with a radiologist for assistance in evaluating whether artifacts may interfere with image interpretation. A qualified service engineer must eliminate any digital detector artifacts that may be clinically objectionable.

The acrylic attenuation block provided by the manufacturer and used for detector calibration must be replaced if it has permanent artifacts that may impact detector calibration.

The recommendations and corrective actions listed in the 1999 ACR Mammography Quality Control Manual must be followed for DICOM printer and film processor artifacts.

Type of attenuator: Acrylic
Thickness of attenuator: 4.0 cm
kVp setting: 28 kVp (Auto-time)

Results

Table XXIV. Artifact evaluation from acrylic phantom

Image receptor size	24x29	24x29	18x24	18x24
Target/Filter	W/Rh	W/Ag	W/Rh	W/Ag
Focal spot	large	large	small	small
Acceptable?	O.K.	O.K.	O.K.	O.K.

Table XXV. Artifact evaluation from DICOM printer

Image Size	18x24	24x29
Acceptable?	O.K.	O.K.

4. kVp Accuracy and Reproducibility

Objective

To assure that the selected kVp is accurate within limits and reproducible between exposures.

Regulatory action levels

The kVp shall be accurate within ±5% of the indicated or selected kVp at:
- The lowest clinical kVp that can be measured by a kVp test device.
- The 28 kVp.
- The highest available clinical kVp.

At 28 kVp, the coefficient of variation of the kVp shall be equal to or less than 0.02.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

kVp meter used: Unfors model; XI

Results

Table XXVI. kVp Accuracy and Reproducibility

Nominal kVp setting	22	23	24	25	26	27	28	29	30	31	32	33
Focal spot	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
mAs setting	30	30	30	30	30	30	30	30	30	30	30	30
Mean kVp	21.98	23.23	23.96	25.42	26.01	26.94	27.59	29.21	30.29	31.63	32.85	34.33
Mean kVp- Nominal kVp	0.02	0.23	-0.04	0.42	0.01	-0.06	-0.41	0.21	0.29	0.63	0.85	1.33
0.05 x Nominal kVp	1.10	1.15	1.20	1.25	1.30	1.35	1.4	1.45	1.5	1.55	1.6	1.65
%Error	0.09	1	-0.17	1.68	0.04	-0.22	-1.46	0.72	0.97	2.03	2.66	4.03

Nominal kVp setting	34	35	36	37	38	39
Focal spot	0.3	0.3	0.3	0.3	0.3	0.3
mAs setting	30	30	30	30	30	30
Mean kVp	35.67	37.06	37.98	39.2	40.09	High range
Mean kVp- Nominal kVp	1.67	2.06	1.98	2.2	2.09	-
0.05 x Nominal kVp	1.7	1.75	1.8	1.85	1.9	1.95
%Error	4.91	5.89	5.5	5.95	5.5	-

5. Beam Quality Assessment- HVL Measurement

Objective

To assure that the half-value layer (HVL) of the x-ray beam is adequate to minimize patient dose without being too excessive to compromise image contrast.

Regulatory action levels

For operating kVp range of less than 50, the measured HVL shall be greater than (kVp/100)+0.03(in mm Al).

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

Dosimetry System Used: Unfors Model XI.

Results

Table XXVII. Beam Quality Assessment- HVL Measurement

Nominal kVp Setting:	26	28	30	32	34
Target/Filter	W/Rh	W/Rh	W/Rh	W/Rh	W/Rh
Paddle in place	Yes	Yes	Yes	Yes	Yes
mAs Setting	30	30	30	30	30
Exposure Measurements:(mGy)					
No Aluminum Filtration, E_{oa}	1.092	1.329	1.56	1.787	2.093
0.2 mm of added Aluminum, $E_{0.2}$	0.813	0.999	1.178	1.359	1.602
0.3 mm of added Aluminum, $E_{0.3}$	0.709	0.871	1.036	1.202	1.423
0.4 mm of added Aluminum, $E_{0.4}$	0.621	0.772	0.916	1.064	1.260
0.5 mm of added Aluminum, $E_{0.5}$	0.554	0.687	0.819	0.954	1.129
0.6 mm of added Aluminum, $E_{0.6}$	0.489	0.605	0.728	0.843	1.007
No Aluminum Filtration, E_{ob}	1.096	1.338	1.568	1.803	2.112
Calculation					
$E_o = (E_{oa} + E_{ob})/2$	1.094	1.333	1.564	1.795	2.102
$E_{1/2} = E_o/2$	0.547	0.666	0.782	0.897	1.051
Exposure greater than $E_{1/2}$: E_a	0.554	0.687	0.819	0.954	1.129
Al thickness at E_a:t_a	0.5	0.5	0.5	0.5	0.5
Exposure less than $E_{1/2}$: E_b	0489	0.605	0.728	0.843	1.007
Al thickness at E_b:t_b	0.6	0.6	0.6	0.6	0.6
Calculated HVL(mmAl)	0.51	0.52	0.54	0.55	0.56
Minimum allowed	0.29	0.31	0.33	0.35	0.37

$$\text{HVL} = \frac{t_b \ln[2E_a/E_o] - t_a \ln[2E_b/E_o]}{\ln[E_a/E_b]}$$

6. System Limiting Spatial Resolution

Objective

To evaluate imaging performance, using the system limiting spatial resolution as a performance indicator that may be easily measured in the field

Regulatory action levels

The system limiting spatial resolution must be greater than 7c/mm (lp/mm) when the bars are at 45° to the anode-cathode axis.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken before any further examinations are performed.

X-ray Tube Manufacturer: Hologic Lorad
Model Number: 4-000-0014

Results

Table XXVIII. Spatial resolution for nominal focal spot size

Nominal focal spot size (mm)	0.3
Target material	W
Nominal kVp setting	28
mAs	100
Limiting resolution in cycles per mm	9

7. Automatic Exposure Control (AEC) Function Performance

Objective

To assess the performance of the automatic exposure control (AEC) function and to maintain consistency in detector signal level for a range of breast thickness and all applicable imaging modes.

To evaluate the Exposure Compensation Function of the AEC.

Regulatory action levels

The pixel value of each individual image corresponding to a breast thickness between 2 and 8 cm at any operating mode shall not very more than 10% of the mean pixel value recorded from all tested breast thickness and operating mode.

Corrective action

If the reproducibility criteria are not met, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

If the average glandular dose criteria are not met, a qualified service engineer must correct the problem before using the system for clinical imaging.

AEC sensor position: 2
Exposure Compensation Step: 0

Results

Table XXIX. Performance capability for AEC

Contact Imaging, LFS with Grid								
Phantom thickness	AEC Mode	Filter	kVp	mAs	Exp Comp Step	Pixel Value	CNR Correction Factor	Corrected Pixel Value*
2cm	Auto-Filter	Rh	25	44.4	0	636.8	1	586.8
4.1cm	"	Rh	27	98.1	0	612.6	1	562.6
6.1cm	"	Rh	30	176	0	621.9	1	571.9
8.1cm	"	Rh	30	270.6	0	721.1	1.5	447.4
Magnification Imaging, SFS without Grid								
4.1cm	Auto-Filter	Rh	27	69	0	626.2	1	576.2
Mean Pixel Value		Pixel Value Range			Allowed Pixel Value			
548.98		447.4 to 586.8			494.1 to 603.9			

*Pixel Value = (ROI mean – DC Offset (50))/ CNR Correction Factor

Table XXX. Exposure compensation

Contact Imaging, LFS with Grid							
Phantom thickness	AEC Mode	Exp Comp	Pixel Value*	Ratio**	Allowed Ratio*		
4cm	Auto-Filter	-3	307.9	0.546	0.50	to	0.61
4cm	"	-2	390.4	0.693	0.63	to	0.77
4cm	"	-1	476.6	0.846	0.77	to	0.94
4cm	"	0	560.9	0.996			
4cm	"	0	567.7	1.008			
4cm	"	0	560.3	0.995			
4cm	"	+1	647.3	1.149	1.04	to	1.27
4cm	"	+2	725.8	1.289	1.17	to	1.43
4cm	"	+3	808.8	1.436	1.31	to	1.60
4cm	"	+4	881.1	1.565	1.44	to	1.76

*Pixel Value = ROI mean – DC Offset (50)
**Pixel Value at given step divided by mean pixel value at step 0

8. Breast Entrance Exposure, Average Glandular Dose, and AEC Reproducibility

Objective

To measure the typical entrance exposure and calculate the corresponding glandular dose for an average patient with approximately 4.5 cm compressed breast thickness of 50% adipose, 50% glandular tissue composition; to assess the reproducibility of the automatic exposure control (AEC).

Regulatory action levels

The coefficient of variation for air kerma shall not exceed 0.05. The average glandular dose delivered during the single cranio-caudal view of an FDA accepted phantom simulating a standard breast shall not exceed 3.0 mGy (0.3 rad) per exposure. The dose shall be determined with technique factor and conditions used clinically for a standard breast.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken before any further examinations are performed.

Results

Imaging mode:	Digital
Field Restriction:	24x29 cm
SID (cm):	66
Source-detector distance (cm):	62
Source-bucky distance (cm):	66
Dosimeter used:	Unfors

Table XXXI. Breast entrance exposure

Breast thickness(cm)	4.5	
Phantom	ACR	
Nominal kVp setting	30	
Target material	W	
Filter	Rh	
AEC Mode	Auto-Filter	
AEC Position	2	
Exp. Compensation step	0	
Measured HVL (mm Al)	0.531	
Exposure	mGy	mAs
Exposure#1	0.512	76
Exposure#2	0.506	76.1
Exposure#3	0.504	75.9
Exposure#4	0.509	76.1
Mean values	0.508	76.02
Standard deviation (SD)	0.004	0.096
Coefficient of variation(CV)	0.007	0.001

9. Radiation Output Rate

Objective

To measure the radiation output rate of the system.

Regulatory action levels

The system shall be capable of producing a minimum output of 2.0 mGy air kerma per second (230mR per second) when operating at 28 kVp in the standard mammography (W/Rh) mode at any SID where the system is designed to operate and when measured by a ionization chamber with its center located 4.5cm above the breast support surface with the compression paddle in place between the source and the ionization chamber.

The system shall be capable of maintaining the required minimum output rate averaged over a 3.0 second period.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken within thirty days of the test date.

SID (cm): 66
Source-detector distance (cm): 62
Dosimeter used: Unfors Model XI

Results

Table XXXII. Radiation output rate

	kVp	Anode	Filter	SID (cm)	mAs	Air Kerma (mGy)
3 sec, 4.5cm above breast support	28	W	Rh	66	320	3.927
	28	W	Rh	66	320	3.911

Dose rate (mGy/sec) = Exp Rate (mR/s) x 0.00873 mGy/mR

10. Phantom Image Quality Evaluation

Objective

To assess the quality and consistency of the mammographic image

Regulatory action levels

The phantom image, evaluated on digital hardcopy film, shall achieve at least a minimum score of 5.0 fibers, 4.0 speck groups, and 4.0 masses, using a phantom accepted by the accreditation body for screen-film mammography. There may be shall fluctuations in scoring of the fibers and masses due to phantom variations. If the fiber score is 4.5 and or the mass score is 3.5, then examine the SNR and high contrast resolution of the system. If both those exceed recommended criteria, then a total score of 4.5 fibers, 4.0 speck and 3.5 masses is acceptable.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified.

If the source is identified as the digital detector, corrective action shall be taken before any further examinations are performed.

If the source is a diagnostic device, imaging on the digital detector can be continued; the diagnostic device shall be corrected before used for mammographic image interpretation.

Phantom used: ACR Phantom GAMMEX (RMI) Model: 156

Results

Table XXXIII. Phantom image quality evaluation

	Current Image	Comments
Date	18 Mar 2009	
kVp setting	28	
mAs setting	96.1	
Number of fibers seen	5	
Number of speck groups seen	4	
Number of masses seen	4	

11. Signal-To-Noise and contrast-To-Noise Measurements

Objective

To assure consistency of the digital image receptor by evaluating the signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) of the digital image receptor

Regulatory action levels

The SNR shall be equal to or greater than 40.

The CNR shall remain within ±15% of the CNR determined as part of the LORAD Selenia FFDM System Evaluation which was completed after installation.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken before any further examinations are performed.

Results

Table XXXIV. Signal-To-Noise and contrast-To-Noise Measurements

	Current	Last	Comment
Date	18 Mar 2009		
Selected kVp	28	28	
Selected mAs	96.1	97	
Selected Filter	Rh	Rh	
Background Mean Value	629.5	630.1	
Background standard deviation	9.9	9.7	
Signal-To-Noise Ratio	58.54	59.80	
Mean Value on top of disk	512.9	515.4	
Standard deviation on top of disk	9.2	9.3	
Contrast-To-Noise ratio	11.78	11.82	
%CNR difference		0.34%	

12. Viewbox Luminance and Room Illuminance

Objective

To assure that the viewboxes used for mammographic image interpretation or quality control meet or exceed minimum levels. To assure that the room illuminance levels are below prescribed levels. To assure that viewing conditions have been optimized.

Regulatory action levels

Appropriate viewbox luminance levels and room illuminance is necessary so that subtle features can be perceived by the radiologist.

Corrective action

None.

Results

Table XXXV. Viewbox Luminance and Room Illuminance

	Radiologist's Viewboxes	
	Reading Area 1	Reading Area 2
Viewbox luminance(cd/m^2)	1652	1557
Illuminance on monitor surface(lux)	62.08	67.80
Illuminance seen by observer(lux)	56.99	55.72
Dirt and marks	N	N
Color difference	N	N
Luminance difference	N	N
Uniformity	Y	Y
Functioning Masks	N	N

13. Diagnostic Review Workstation QC

Objective

To assure consistency of the brightness, contrast and image presentation of the radiologist's diagnostic review workstation

Regulatory action levels

The computer software analyzes the results and provides an indication if the monitors met the pre-programmed control limits.

Corrective action

If the software indicates that the control limits are exceeded, the problem shall be corrected before any clinical or phantom images are read on the workstation.

Results

Table XXXVI. Diagnostic Review Workstation QC

Photometer Serial Number; 143473

	Left Monitor	Right Monitor	Comment
Monitor Serial Number	1890033200	1890024831	
White Level Performance	313.9 cd/m^2	311.9 cd/m^2	
Black Level Performance*	0.66 cd/m^2	0.65 cd/m^2	
Quality Level Performance	100%	100%	
Uniformity Performance*	0%	0%	

***** Black Level Performance and Uniformity Performance only apply to CRT displays. If LCD displays are used, these checks are not performed and "N/A" shall be entered.

14. Detector Ghosting (Optional)

Objective

To assure that the level of detector ghosting does not interfere with image quality.

Regulatory action levels

The measured Ghost Image Factor must be within ±0.3 for consecutive images acquired within approximately 1 minute of each other.

Corrective action

If the test results fall outside the control limits, the source of the problem shall be identified and corrective action shall be taken before any further examinations are performed.

Results

Table XXXVII. Test Exposure

	Filter	kVp	Exposure Step	mAs
Exposure 1	Rh	28	0	97.4
Exposure 2	Rh	28	0	104.3

Region 1 Factor	Region 2	Region 3	Ghost Image
668.1	617.8	617.8	0

APPENDIX C

THE PATIENT DATA OF BREAST SCREENING

Table I. The patient data underwent breast screening from molybdenum target (457 data).

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
1	54	LCC	25	47.8	3.3	53.4	0.95	4.55	Mo/Mo
2	54	RCC	25	62.6	3.4	66.75	1.22	5.97	Mo/Mo
3	51	LCC	25	68.6	3.4	57.84	1.34	6.55	Mo/Mo
4	54	LCC	26	44.7	3.6	53.4	0.99	4.88	Mo/Mo
5	43	LCC	26	59.7	3.6	57.84	1.32	6.52	Mo/Mo
6	51	RCC	26	64.6	3.7	53.4	1.4	7.08	Mo/Mo
7	46	RCC	26	47.9	3.8	44.5	1.01	5.27	Mo/Mo
8	43	LCC	26	55.7	3.8	57.84	1.18	6.12	Mo/Mo
9	43	RCC	26	74.8	3.8	62.29	1.58	8.22	Mo/Mo
10	43	LCC	26	88.9	3.8	57.84	1.88	9.77	Mo/Mo
11	43	RCC	26	58.6	3.9	57.84	1.21	6.46	Mo/Mo
12	41	LCC	27	69.5	4	44.5	1.65	8.67	Mo/Mo
13	47	RCC	27	83.8	4	66.75	1.99	10.5	Mo/Mo
14	46	LCC	27	51.6	4.1	48.95	1.2	6.46	Mo/Mo
15	42	LCC	27	55.5	4.1	57.84	1.29	6.95	Mo/Mo
16	57	RCC	27	56.6	4.1	53.4	1.31	7.08	Mo/Mo
17	57	LCC	27	57.9	4.1	57.84	1.34	7.25	Mo/Mo
18	42	RCC	27	62.6	4.1	57.84	1.45	7.83	Mo/Mo
19	55	LCC	27	76.6	4.1	66.75	1.78	9.59	Mo/Mo
20	41	RCC	27	71.6	4.2	44.5	1.63	8.99	Mo/Mo
21	53	RCC	27	90.8	4.2	66.75	2.07	11.4	Mo/Mo
22	46	LCC	27	100.3	4.2	66.75	2.28	12.6	Mo/Mo
23	53	RCC	27	71.7	4.3	80.09	1.6	9.03	Mo/Mo
24	54	RCC	27	49.6	4.4	44.5	1.08	6.27	Mo/Mo
25	47	LCC	27	58.5	4.4	62.29	1.28	7.39	Mo/Mo
26	54	LCC	27	65.6	4.4	53.4	1.43	8.29	Mo/Mo
27	42	LCC	27	90.7	4.4	62.29	1.98	11.5	Mo/Mo
28	44	RCC	28	50.9	4.5	71.19	1.26	7.22	Mo/Mo
29	52	LCC	28	55.7	4.5	57.84	1.38	7.9	Mo/Mo
30	54	RCC	28	61.5	4.5	62.29	1.52	8.72	Mo/Mo
31	53	LCC	28	62.8	4.5	84.55	1.56	8.91	Mo/Mo
32	50	LCC	28	67.5	4.5	53.4	1.67	9.57	Mo/Mo
33	48	RCC	28	75.7	4.5	71.19	1.88	10.7	Mo/Mo
34	53	LCC	28	84.4	4.5	62.29	2.09	12	Mo/Mo
35	43	RCC	28	92.6	4.5	57.84	2.3	13.1	Mo/Mo

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
36	41	RCC	28	38.3	4.6	53.4	0.93	5.45	Mo/Mo
37	50	LCC	28	54.5	4.6	57.84	1.33	7.76	Mo/Mo
38	54	RCC	28	60.6	4.6	62.29	1.47	8.62	Mo/Mo
39	58	RCC	28	65.7	4.6	84.55	1.6	9.35	Mo/Mo
40	60	LCC	28	71.7	4.6	71.19	1.74	10.2	Mo/Mo
41	56	LCC	28	42.4	4.7	66.75	1.01	6.05	Mo/Mo
42	44	LCC	28	49.7	4.7	62.29	1.19	7.1	Mo/Mo
43	53	LCC	28	51.8	4.7	53.4	1.24	7.4	Mo/Mo
44	59	LCC	28	54.6	4.7	62.29	1.3	7.8	Mo/Mo
45	43	LCC	28	55.7	4.7	53.4	1.33	7.95	Mo/Mo
46	54	LCC	28	57.7	4.7	62.29	1.38	8.24	Mo/Mo
47	49	RCC	28	73.5	4.7	80.09	1.75	10.5	Mo/Mo
48	47	RCC	28	73.6	4.7	89	1.76	10.5	Mo/Mo
49	48	LCC	28	80.6	4.7	57.84	1.92	11.5	Mo/Mo
50	58	LCC	28	58.5	4.8	62.29	1.37	8.38	Mo/Mo
51	43	LCC	28	61.6	4.8	53.4	1.44	8.83	Mo/Mo
52	43	RCC	28	64.5	4.8	62.29	1.51	9.24	Mo/Mo
53	45	RCC	28	65.6	4.8	48.95	1.54	9.4	Mo/Mo
54	60	RCC	28	66.8	4.8	66.75	1.57	9.57	Mo/Mo
55	49	LCC	28	69.9	4.8	80.09	1.64	10	Mo/Mo
56	47	LCC	28	79.6	4.8	48.95	1.87	11.4	Mo/Mo
57	45	RCC	28	85.9	4.8	57.84	2.01	12.3	Mo/Mo
58	46	RCC	28	102.9	4.8	57.84	2.41	14.7	Mo/Mo
59	54	LCC	28	53.7	4.9	75.65	1.24	7.72	Mo/Mo
60	53	LCC	28	57.6	4.9	53.4	1.33	8.28	Mo/Mo
61	43	RCC	28	61.7	4.9	57.84	1.42	8.87	Mo/Mo
62	47	RCC	28	63.8	4.9	62.29	1.47	9.17	Mo/Mo
63	50	RCC	28	64.5	4.9	62.29	1.49	9.27	Mo/Mo
64	49	LCC	28	67.5	4.9	62.29	1.55	9.7	Mo/Mo
65	47	RCC	28	74.7	4.9	48.95	1.72	10.7	Mo/Mo
66	54	LCC	28	76.5	4.9	57.84	1.76	11	Mo/Mo
67	49	RCC	28	77.8	4.9	48.95	1.79	11.2	Mo/Mo
68	49	RCC	28	82.6	4.9	66.75	1.9	11.9	Mo/Mo
69	48	LCC	28	83.4	4.9	57.84	1.92	12	Mo/Mo
70	50	LCC	28	84.5	4.9	75.65	1.95	12.1	Mo/Mo
71	46	RCC	28	94.4	4.9	57.84	2.17	13.6	Mo/Mo
72	49	LCC	28	105.8	4.9	57.84	2.44	15.2	Mo/Mo
73	46	LCC	28	106.6	4.9	75.65	2.45	15.3	Mo/Mo
74	49	RCC	28	109.4	4.9	57.84	2.52	15.7	Mo/Mo

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
75	53	RCC	29	49.6	5	57.84	1.29	7.95	Mo/Mo
76	50	RCC	29	51.7	5	53.4	1.34	8.29	Mo/Mo
77	45	LCC	29	60.7	5	48.95	1.57	9.73	Mo/Mo
78	53	RCC	29	63.6	5	62.29	1.65	10.2	Mo/Mo
79	41	LCC	29	66.6	5	62.29	1.73	10.7	Mo/Mo
80	52	RCC	29	74.9	5	75.65	1.94	12	Mo/Mo
81	51	LCC	29	75.6	5	66.75	1.96	12.1	Mo/Mo
82	55	LCC	29	75.5	5	57.84	1.96	12.1	Mo/Mo
83	45	LCC	29	76.7	5	66.75	1.99	12.3	Mo/Mo
84	45	RCC	29	80.6	5	71.19	2.09	12.9	Mo/Mo
85	42	RCC	29	85.7	5	62.29	2.22	13.7	Mo/Mo
86	59	LCC	29	46.2	5.1	71.19	1.18	7.43	Mo/Mo
87	54	RCC	29	55.7	5.1	75.65	1.42	8.96	Mo/Mo
88	59	RCC	29	57.8	5.1	48.95	1.47	9.29	Mo/Mo
89	43	LCC	29	60.7	5.1	53.4	1.55	9.76	Mo/Mo
90	52	LCC	29	67.8	5.1	53.4	1.73	10.9	Mo/Mo
91	50	RCC	29	71.9	5.1	71.19	1.83	11.6	Mo/Mo
92	45	LCC	29	74.8	5.1	80.09	1.91	12	Mo/Mo
93	50	RCC	29	76.6	5.1	53.4	1.95	12.3	Mo/Mo
94	55	RCC	29	79.7	5.1	62.29	2.03	12.8	Mo/Mo
95	49	LCC	29	84.6	5.1	71.19	2.16	13.6	Mo/Mo
96	55	RCC	29	84.6	5.1	53.4	2.16	13.6	Mo/Mo
97	49	RCC	29	85.6	5.1	89	2.18	13.8	Mo/Mo
98	58	LCC	29	45.5	5.2	48.95	1.14	7.34	Mo/Mo
99	56	RCC	29	49.7	5.2	71.19	1.25	8.02	Mo/Mo
100	50	RCC	29	58.7	5.2	53.4	1.47	9.47	Mo/Mo
101	52	RCC	29	63.6	5.2	53.4	1.59	10.3	Mo/Mo
102	58	RCC	29	66.5	5.2	57.84	1.67	10.7	Mo/Mo
103	44	RCC	29	67.9	5.2	53.4	1.7	11	Mo/Mo
104	48	RCC	29	68.8	5.2	48.95	1.72	11.1	Mo/Mo
105	44	LCC	29	69.5	5.2	48.95	1.74	11.2	Mo/Mo
106	45	RCC	29	69.6	5.2	53.4	1.74	11.2	Mo/Mo
107	44	RCC	29	70.5	5.2	57.84	1.77	11.4	Mo/Mo
108	47	RCC	29	72.4	5.2	57.84	1.81	11.7	Mo/Mo
109	49	LCC	29	72.5	5.2	53.4	1.82	11.7	Mo/Mo
110	46	LCC	29	76.4	5.2	57.84	1.92	12.3	Mo/Mo
111	49	LCC	29	76.6	5.2	48.95	1.92	12.4	Mo/Mo
112	46	RCC	29	80.6	5.2	71.19	2.02	13	Mo/Mo
113	46	LCC	29	87.6	5.2	71.19	2.2	14.1	Mo/Mo

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
114	46	LCC	29	92.5	5.2	57.84	2.32	14.9	Mo/Mo
115	46	RCC	29	92.7	5.2	66.75	2.32	15	Mo/Mo
116	46	RCC	29	95.6	5.2	62.29	2.4	15.4	Mo/Mo
117	43	RCC	29	58.7	5.3	44.5	1.45	9.5	Mo/Mo
118	59	LCC	29	62.7	5.3	48.95	1.55	10.2	Mo/Mo
119	59	RCC	29	68.7	5.3	66.75	1.69	11.1	Mo/Mo
120	57	RCC	29	69.5	5.3	57.84	1.71	11.3	Mo/Mo
121	47	RCC	29	70.7	5.3	53.4	1.74	11.4	Mo/Mo
122	52	LCC	29	70.7	5.3	57.84	1.74	11.4	Mo/Mo
123	56	LCC	29	70.7	5.3	57.84	1.74	11.4	Mo/Mo
124	57	RCC	29	71.7	5.3	48.95	1.77	11.6	Mo/Mo
125	52	RCC	29	73.6	5.3	48.95	1.81	11.9	Mo/Mo
126	47	LCC	29	73.7	5.3	57.84	1.82	11.9	Mo/Mo
127	45	LCC	29	81.4	5.3	62.29	2.01	13.2	Mo/Mo
128	47	LCC	29	82.9	5.3	57.84	2.04	13.4	Mo/Mo
129	47	LCC	29	99.4	5.3	53.4	2.45	16.1	Mo/Mo
130	55	RCC	29	39.5	5.4	57.84	0.96	6.42	Mo/Mo
131	60	LCC	29	40.2	5.4	53.4	0.98	6.53	Mo/Mo
132	41	LCC	29	51.5	5.4	57.84	1.25	8.37	Mo/Mo
133	42	RCC	29	56.3	5.4	66.75	1.37	9.15	Mo/Mo
134	41	LCC	29	58.5	5.4	57.84	1.42	9.5	Mo/Mo
135	59	LCC	29	58.6	5.4	75.65	1.42	9.52	Mo/Mo
136	52	RCC	29	62.7	5.4	57.84	1.52	10.2	Mo/Mo
137	57	LCC	29	63.6	5.4	48.95	1.54	10.3	Mo/Mo
138	55	RCC	29	65.7	5.4	57.84	1.59	10.7	Mo/Mo
139	54	RCC	29	69.5	5.4	57.84	1.69	11.3	Mo/Mo
140	55	LCC	29	72.4	5.4	48.95	1.76	11.8	Mo/Mo
141	51	RCC	29	78.4	5.4	66.75	1.9	12.7	Mo/Mo
142	53	LCC	29	78.5	5.4	53.4	1.9	12.8	Mo/Mo
143	59	LCC	29	79.7	5.4	62.29	1.93	12.9	Mo/Mo
144	45	LCC	29	81.3	5.4	71.19	1.97	13.2	Mo/Mo
145	46	LCC	29	84.6	5.4	62.29	2.05	13.7	Mo/Mo
146	47	LCC	29	85.4	5.4	62.29	2.07	13.9	Mo/Mo
147	45	RCC	29	89.5	5.4	57.84	2.17	14.5	Mo/Mo
148	45	RCC	29	89.3	5.4	84.55	2.17	14.5	Mo/Mo
149	46	RCC	29	91.4	5.4	62.29	2.22	14.8	Mo/Mo
150	49	LCC	29	92.6	5.4	53.4	2.25	15	Mo/Mo
151	45	LCC	29	93.8	5.4	48.95	2.28	15.2	Mo/Mo
152	45	RCC	29	121.9	5.4	75.65	2.96	19.8	Mo/Mo
153	60	RCC	30	37.3	5.5	53.4	1.01	6.72	Mo/Mo

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
154	50	LCC	30	50.5	5.5	75.65	1.37	9.09	Mo/Mo
155	45	LCC	30	55.4	5.5	44.5	1.5	9.97	Mo/Mo
156	41	RCC	30	56.8	5.5	62.29	1.54	10.2	Mo/Mo
157	58	LCC	30	59.5	5.5	62.29	1.61	10.7	Mo/Mo
158	54	RCC	30	60.6	5.5	71.19	1.64	10.9	Mo/Mo
159	54	RCC	30	61.8	5.5	57.84	1.68	11.1	Mo/Mo
160	58	RCC	30	64.7	5.5	62.29	1.75	11.6	Mo/Mo
161	60	RCC	30	64.6	5.5	71.19	1.75	11.6	Mo/Mo
162	43	LCC	30	64.8	5.5	57.84	1.76	11.7	Mo/Mo
163	52	LCC	30	69.6	5.5	62.29	1.89	12.5	Mo/Mo
164	57	RCC	30	76.7	5.5	106.8	2.08	13.8	Mo/Mo
165	58	LCC	30	78.4	5.5	80.09	2.13	14.1	Mo/Mo
166	55	LCC	30	87.5	5.5	57.84	2.37	15.8	Mo/Mo
167	44	LCC	30	100.3	5.5	66.75	2.72	18.1	Mo/Mo
168	42	LCC	30	34.7	5.6	53.4	0.93	6.27	Mo/Mo
169	42	LCC	30	41.6	5.6	62.29	1.11	7.52	Mo/Mo
170	56	LCC	30	58.4	5.6	62.29	1.56	10.6	Mo/Mo
171	60	LCC	30	62.7	5.6	62.29	1.67	11.3	Mo/Mo
172	41	RCC	30	65.6	5.6	57.84	1.75	11.9	Mo/Mo
173	45	LCC	30	75.6	5.6	53.4	2.02	13.7	Mo/Mo
174	43	LCC	30	80.6	5.6	53.4	2.15	14.6	Mo/Mo
175	43	LCC	30	106.4	5.6	66.75	2.84	19.2	Mo/Mo
176	55	LCC	30	31.6	5.7	53.4	0.83	5.73	Mo/Mo
177	46	RCC	30	35.7	5.7	62.29	0.94	6.47	Mo/Mo
178	59	LCC	30	41.5	5.7	71.19	1.09	7.52	Mo/Mo
179	44	LCC	30	47.3	5.7	75.65	1.24	8.57	Mo/Mo
180	54	RCC	30	49.7	5.7	62.29	1.31	9.01	Mo/Mo
181	49	RCC	30	57.8	5.7	57.84	1.52	10.5	Mo/Mo
182	52	LCC	30	59.6	5.7	66.75	1.57	10.8	Mo/Mo
183	56	LCC	30	61.7	5.7	57.84	1.62	11.2	Mo/Mo
184	54	LCC	30	62.6	5.7	66.75	1.65	11.3	Mo/Mo
185	60	LCC	30	62.9	5.7	66.75	1.65	11.4	Mo/Mo
186	50	RCC	30	66.5	5.7	62.29	1.75	12.1	Mo/Mo
187	58	RCC	30	58.6	5.7	53.4	1.77	10.6	Mo/Mo
188	59	RCC	30	69.5	5.7	62.29	1.83	12.6	Mo/Mo
189	60	RCC	30	69.6	5.7	62.29	1.83	12.6	Mo/Mo
190	41	LCC	30	70.7	5.7	53.4	1.86	12.8	Mo/Mo
191	45	LCC	30	72.3	5.7	80.09	1.9	13.1	Mo/Mo
192	49	LCC	30	74.6	5.7	71.19	1.96	13.5	Mo/Mo
193	57	LCC	30	75	5.7	53.4	1.97	13.6	Mo/Mo

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
194	46	RCC	30	79.4	5.7	57.84	2.09	14.4	Mo/Mo
195	49	RCC	30	81.3	5.7	71.19	2.14	14.7	Mo/Mo
196	40	LCC	30	89.4	5.7	57.84	2.35	16.2	Mo/Mo
197	48	LCC	30	89.4	5.7	66.75	2.35	16.2	Mo/Mo
198	43	RCC	30	93.8	5.7	62.29	2.47	17	Mo/Mo
199	45	LCC	30	93.9	5.7	66.75	2.47	17	Mo/Mo
200	50	LCC	30	45.5	5.8	62.29	1.18	8.28	Mo/Mo
201	55	RCC	30	52.8	5.8	66.75	1.37	9.6	Mo/Mo
202	59	RCC	30	57.6	5.8	57.84	1.49	10.5	Mo/Mo
203	53	LCC	30	58.6	5.8	53.4	1.52	10.7	Mo/Mo
204	48	LCC	30	62.7	5.8	53.4	1.62	11.4	Mo/Mo
205	48	RCC	30	62.7	5.8	71.19	1.62	11.4	Mo/Mo
206	43	RCC	30	63.6	5.8	66.75	1.65	11.6	Mo/Mo
207	55	RCC	30	75.6	5.8	53.4	1.96	13.8	Mo/Mo
208	54	RCC	30	76.5	5.8	62.29	1.98	13.9	Mo/Mo
209	40	RCC	30	79.7	5.8	66.75	2.07	14.5	Mo/Mo
210	53	RCC	30	80.6	5.8	57.84	2.09	14.7	Mo/Mo
211	49	LCC	30	83.9	5.8	48.95	2.17	15.3	Mo/Mo
212	45	LCC	30	98.2	5.8	57.84	2.54	17.9	Mo/Mo
213	49	RCC	30	105.8	5.8	71.19	2.74	19.2	Mo/Mo
214	45	RCC	30	106.4	5.8	57.84	2.76	19.4	Mo/Mo
215	43	LCC	30	111.4	5.8	71.19	2.89	20.3	Mo/Mo
216	50	RCC	30	46.2	5.9	62.29	1.18	8.43	Mo/Mo
217	52	RCC	30	52.8	5.9	66.75	1.35	9.64	Mo/Mo
218	55	LCC	30	52.8	5.9	53.4	1.35	9.64	Mo/Mo
219	50	LCC	30	63.6	5.9	62.29	1.62	11.6	Mo/Mo
220	58	LCC	30	65.6	5.9	53.4	1.68	12	Mo/Mo
221	56	RCC	30	70.6	5.9	57.84	1.8	12.9	Mo/Mo
222	54	LCC	30	72.6	5.9	71.19	1.85	13.3	Mo/Mo
223	58	LCC	30	63.4	5.9	57.84	1.86	11.6	Mo/Mo
224	56	RCC	30	73.5	5.9	62.29	1.88	13.4	Mo/Mo
225	50	RCC	30	77.4	5.9	48.95	1.98	14.1	Mo/Mo
226	58	RCC	30	78.3	5.9	75.65	2	14.3	Mo/Mo
227	42	LCC	30	81.4	5.9	57.84	2.08	14.9	Mo/Mo
228	53	RCC	30	83.8	5.9	53.4	2.14	15.3	Mo/Mo
229	40	LCC	30	92.8	5.9	71.19	2.37	16.9	Mo/Mo
230	50	RCC	30	97.6	5.9	71.19	2.49	17.8	Mo/Mo
231	45	RCC	30	121.8	5.9	57.84	3.11	22.2	Mo/Mo
232	50	RCC	32	52.8	7	62.29	1.18	7.89	Mo/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
233	52	LCC	32	52.8	7	57.84	1.18	7.89	Mo/Rh
234	57	LCC	32	54.7	7	53.4	1.23	8.17	Mo/Rh
235	42	LCC	32	55.7	7	71.19	1.25	8.32	Mo/Rh
236	49	RCC	32	62.7	7	57.84	1.41	9.37	Mo/Rh
237	52	LCC	32	62.7	7	53.4	1.41	9.37	Mo/Rh
238	58	LCC	32	63.5	7	57.84	1.42	9.49	Mo/Rh
239	44	RCC	32	66.6	7	71.19	1.49	9.95	Mo/Rh
240	50	LCC	32	67.9	7	57.84	1.52	10.1	Mo/Rh
241	52	RCC	32	72.3	7	62.29	1.62	10.8	Mo/Rh
242	50	RCC	32	73.7	7	48.95	1.65	11	Mo/Rh
243	54	RCC	32	76.5	7	62.29	1.71	11.4	Mo/Rh
244	50	RCC	32	76.6	7	62.29	1.72	11.4	Mo/Rh
245	56	LCC	32	78.3	7	62.29	1.76	11.7	Mo/Rh
246	56	LCC	32	79.7	7	66.75	1.79	11.9	Mo/Rh
247	49	LCC	32	80.5	7	53.4	1.8	12	Mo/Rh
248	59	RCC	32	83.7	7	71.19	1.88	12.5	Mo/Rh
249	47	RCC	32	85.6	7	66.75	1.92	12.8	Mo/Rh
250	49	LCC	32	86.4	7	57.84	1.94	12.9	Mo/Rh
251	53	RCC	32	86.4	7	62.29	1.94	12.9	Mo/Rh
252	52	LCC	32	90.8	7	44.5	2.04	13.6	Mo/Rh
253	40	LCC	32	94.5	7	57.84	2.12	14.1	Mo/Rh
254	52	RCC	32	94.6	7	62.29	2.12	14.1	Mo/Rh
255	40	RCC	32	97.5	7	66.75	2.19	14.6	Mo/Rh
256	47	LCC	32	98	7	62.29	2.2	14.6	Mo/Rh
257	48	RCC	32	98.1	7	62.29	2.2	14.7	Mo/Rh
258	48	RCC	32	100.3	7	71.19	2.25	15	Mo/Rh
259	60	RCC	32	101.2	7	75.65	2.27	15.1	Mo/Rh
260	46	RCC	32	102.6	7	43.5	2.3	15.3	Mo/Rh
261	43	RCC	32	116.2	7	48.95	2.6	17.4	Mo/Rh
262	48	RCC	32	117	7	84.55	2.62	17.5	Mo/Rh
263	43	LCC	32	118.3	7	57.84	2.65	17.7	Mo/Rh
264	50	LCC	32	123.7	7	53.4	2.77	18.5	Mo/Rh
265	50	LCC	32	126.8	7	80.09	2.84	19	Mo/Rh
266	50	RCC	32	144.9	7	66.75	3.25	21.7	Mo/Rh
267	47	RCC	32	48.4	7.1	62.29	1.07	7.26	Mo/Rh
268	47	LCC	32	60.6	7.1	62.29	1.34	9.09	Mo/Rh
269	49	LCC	32	63.4	7.1	57.84	1.41	9.51	Mo/Rh
270	58	RCC	32	63.6	7.1	62.29	1.41	9.54	Mo/Rh
271	59	LCC	32	76.6	7.1	66.75	1.7	11.5	Mo/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
272	56	LCC	32	79.7	7.1	62.29	1.77	12	Mo/Rh
273	47	LCC	32	83.8	7.1	62.29	1.86	12.6	Mo/Rh
274	45	RCC	32	91.5	7.1	53.4	2.03	13.7	Mo/Rh
275	45	LCC	32	107.9	7.1	66.75	2.39	16.2	Mo/Rh
276	48	LCC	32	113.3	7.1	71.19	2.51	17	Mo/Rh
277	41	LCC	32	118.2	7.1	48.95	2.62	17.7	Mo/Rh
278	41	LCC	32	129.5	7.1	57.84	2.87	19.4	Mo/Rh
279	52	RCC	32	132.3	7.1	66.75	2.93	19.8	Mo/Rh
280	50	RCC	32	139.1	7.1	84.5	3.08	20.9	Mo/Rh
281	51	RCC	32	52.8	7.2	57.84	1.16	7.95	Mo/Rh
282	55	LCC	32	62.7	7.2	62.29	1.38	9.44	Mo/Rh
283	41	LCC	32	64.7	7.2	62.29	1.42	9.74	Mo/Rh
284	43	LCC	32	65.6	7.2	44.5	1.44	9.87	Mo/Rh
285	56	LCC	32	75.6	7.2	66.75	1.66	11.4	Mo/Rh
286	45	LCC	32	79.4	7.2	48.95	1.74	12	Mo/Rh
287	49	RCC	32	86.4	7.2	48.95	1.89	13	Mo/Rh
288	52	RCC	32	94.5	7.2	57.84	2.07	14.2	Mo/Rh
289	50	LCC	32	103.1	7.2	71.19	2.26	15.5	Mo/Rh
290	51	RCC	32	103.2	7.2	66.75	2.26	15.5	Mo/Rh
291	49	LCC	32	105.8	7.2	62.29	2.32	15.9	Mo/Rh
292	49	RCC	32	108.8	7.2	66.75	2.39	16.4	Mo/Rh
293	52	LCC	32	123.8	7.2	66.29	2.72	18.6	Mo/Rh
294	49	RCC	32	136.2	7.2	62.29	2.99	20.5	Mo/Rh
295	45	LCC	32	64.6	7.3	62.29	1.4	9.76	Mo/Rh
296	46	LCC	32	68.7	7.3	57.84	1.49	10.4	Mo/Rh
297	45	RCC	32	70.6	7.3	66.75	1.53	10.7	Mo/Rh
298	52	RCC	32	75.6	7.3	57.84	1.64	11.4	Mo/Rh
299	59	LCC	32	76.7	7.3	66.75	1.66	11.6	Mo/Rh
300	56	RCC	32	83.7	7.3	53.4	1.82	12.6	Mo/Rh
301	55	LCC	32	83.8	7.3	57.84	1.82	12.7	Mo/Rh
302	44	RCC	32	85.7	7.3	44.5	1.86	12.9	Mo/Rh
303	52	RCC	32	85.6	7.3	62.29	1.86	12.9	Mo/Rh
304	51	LCC	32	87.5	7.3	44.5	1.9	13.2	Mo/Rh
305	47	RCC	32	88.3	7.3	62.29	1.92	13.3	Mo/Rh
306	44	LCC	32	91.5	7.3	57.84	1.99	13.8	Mo/Rh
307	51	LCC	32	106.2	7.3	66.75	2.3	16	Mo/Rh
308	41	RCC	32	114.2	7.3	48.95	2.48	17.2	Mo/Rh
309	49	LCC	32	46.4	7.4	62.29	1	7.03	Mo/Rh
310	42	RCC	32	55.6	7.4	62.29	1.19	8.43	Mo/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
311	55	LCC	32	69.5	7.4	66.75	1.49	10.5	Mo/Rh
312	47	LCC	32	83.8	7.4	62.29	1.8	12.7	Mo/Rh
313	52	RCC	32	101.1	7.4	44.5	2.17	15.3	Mo/Rh
314	53	LCC	32	126.9	7.4	62.29	2.73	19.2	Mo/Rh
315	50	RCC	32	37.6	7.5	57.84	0.8	5.72	Mo/Rh
316	57	RCC	32	38.7	7.5	62.29	0.82	5.89	Mo/Rh
317	57	LCC	32	68.7	7.5	57.84	1.46	10.4	Mo/Rh
318	58	RCC	32	75.6	7.5	75.65	1.61	11.5	Mo/Rh
319	47	LCC	32	84.6	7.5	84.55	1.8	12.9	Mo/Rh
320	51	LCC	32	84.6	7.5	53.4	1.8	12.9	Mo/Rh
321	53	LCC	32	85.6	7.5	48.95	1.82	13	Mo/Rh
322	57	RCC	32	85.5	7.5	48.95	1.82	13	Mo/Rh
323	51	LCC	32	88.3	7.5	62.29	1.88	13.4	Mo/Rh
324	48	RCC	32	90.8	7.5	66.75	1.93	13.8	Mo/Rh
325	48	LCC	32	106.4	7.5	66.75	2.26	16.2	Mo/Rh
326	51	RCC	32	109.7	7.5	66.75	2.33	16.7	Mo/Rh
327	53	RCC	32	113.3	7.5	71.19	2.41	17.2	Mo/Rh
328	42	RCC	32	114.4	7.5	53.4	2.43	17.4	Mo/Rh
329	40	RCC	32	121.8	7.5	62.29	2.59	18.5	Mo/Rh
330	44	LCC	32	128.7	7.5	57.84	2.74	19.6	Mo/Rh
331	48	RCC	32	130.6	7.5	71.19	2.78	19.9	Mo/Rh
332	49	LCC	32	190.6	7.5	62.29	4.05	29	Mo/Rh
333	53	RCC	32	69.5	7.6	53.4	1.46	10.6	Mo/Rh
334	51	LCC	32	70.7	7.6	57.84	1.49	10.8	Mo/Rh
335	41	RCC	32	75.8	7.6	62.29	1.6	11.6	Mo/Rh
336	41	LCC	32	82.8	7.6	71.19	1.74	12.6	Mo/Rh
337	51	LCC	32	92.8	7.6	57.84	1.95	14.2	Mo/Rh
338	57	RCC	32	93.8	7.6	57.84	1.97	14.3	Mo/Rh
339	58	RCC	32	93.8	7.6	57.84	1.97	14.3	Mo/Rh
340	55	RCC	32	95.6	7.6	53.4	2.01	14.6	Mo/Rh
341	46	RCC	32	96.4	7.6	57.84	2.03	14.7	Mo/Rh
342	44	RCC	32	101.3	7.6	53.4	2.13	15.5	Mo/Rh
343	55	RCC	32	105.8	7.6	57.84	2.23	16.2	Mo/Rh
344	41	RCC	32	116.2	7.6	62.29	2.45	17.7	Mo/Rh
345	49	RCC	32	120.4	7.6	71.19	2.53	18.4	Mo/Rh
346	53	LCC	32	34.6	7.7	62.29	0.72	5.3	Mo/Rh
347	48	RCC	32	79.6	7.7	66.75	1.66	12.2	Mo/Rh
348	56	RCC	32	79.7	7.7	57.84	1.66	12.2	Mo/Rh
349	49	RCC	32	82.8	7.7	97.9	1.73	12.7	Mo/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
350	51	RCC	32	87.5	7.7	62.29	1.82	13.4	Mo/Rh
351	53	RCC	32	89.3	7.7	53.4	1.86	13.7	Mo/Rh
352	49	RCC	32	91.5	7.7	62.29	1.91	14	Mo/Rh
353	56	LCC	32	94.6	7.7	62.29	1.97	14.5	Mo/Rh
354	51	LCC	32	97.6	7.7	62.29	2.03	15	Mo/Rh
355	51	RCC	32	105.8	7.7	57.84	2.2	16.2	Mo/Rh
356	59	LCC	32	100.3	7.7	62.29	2.29	15.4	Mo/Rh
357	54	LCC	32	110.7	7.7	57.84	2.31	17	Mo/Rh
358	42	LCC	32	115.1	7.7	53.4	2.4	17.6	Mo/Rh
359	48	LCC	32	119.8	7.7	66.75	2.5	18.4	Mo/Rh
360	53	RCC	32	125.6	7.7	62.29	2.62	19.2	Mo/Rh
361	52	RCC	32	38.7	7.8	71.19	0.8	5.95	Mo/Rh
362	50	LCC	32	39.5	7.8	62.29	0.82	6.07	Mo/Rh
363	55	RCC	32	72.2	7.8	71.19	1.49	11.1	Mo/Rh
364	52	RCC	32	77.5	7.8	53.4	1.6	11.9	Mo/Rh
365	47	LCC	32	78.5	7.8	62.29	1.86	12.1	Mo/Rh
366	47	LCC	32	100.4	7.8	62.29	2.07	15.4	Mo/Rh
367	52	RCC	32	100.2	7.8	57.84	2.07	15.4	Mo/Rh
368	47	RCC	32	105.8	7.8	89	2.18	16.3	Mo/Rh
369	57	RCC	32	105.9	7.8	66.75	2.19	16.3	Mo/Rh
370	45	LCC	32	116.9	7.8	66.75	2.41	18	Mo/Rh
371	41	LCC	32	118.9	7.8	53.4	2.45	18.3	Mo/Rh
372	47	RCC	32	158.8	7.8	62.29	3.28	24.4	Mo/Rh
373	57	LCC	32	42.5	7.9	57.84	0.87	6.56	Mo/Rh
374	50	LCC	32	77.5	7.9	62.29	1.58	12	Mo/Rh
375	41	RCC	32	89.4	7.9	57.84	1.83	13.8	Mo/Rh
376	45	LCC	32	98.2	7.9	57.84	2.01	15.2	Mo/Rh
377	45	RCC	32	99.5	7.9	53.4	2.03	15.4	Mo/Rh
378	59	RCC	32	111.5	7.9	62.29	2.28	17.2	Mo/Rh
379	55	LCC	32	123.9	7.9	48.95	2.53	19.1	Mo/Rh
380	53	LCC	33	54.8	8	48.95	1.23	9.27	Mo/Rh
381	58	RCC	33	71.8	8	62.29	1.61	12.1	Mo/Rh
382	55	RCC	33	74.3	8	53.4	1.67	12.6	Mo/Rh
383	56	LCC	33	74.4	8	71.19	1.67	12.6	Mo/Rh
384	56	RCC	33	77.1	8	66.75	1.73	13	Mo/Rh
385	57	LCC	33	78.8	8	71.19	1.77	13.3	Mo/Rh
386	47	LCC	33	82.8	8	66.75	1.86	14	Mo/Rh
387	47	RCC	33	84.4	8	75.65	1.9	14.3	Mo/Rh
388	50	RCC	33	87.6	8	48.95	1.97	14.8	Mo/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
389	47	RCC	33	88.6	8	62.29	1.99	15	Mo/Rh
390	49	RCC	33	106.5	8	62.29	2.39	18	Mo/Rh
391	54	RCC	33	111	8	57.84	2.5	18.8	Mo/Rh
392	50	LCC	33	111.7	8	71.19	2.51	18.9	Mo/Rh
393	52	RCC	33	113.9	8	57.84	2.56	19.3	Mo/Rh
394	53	RCC	33	32.9	8.1	62.29	0.73	5.59	Mo/Rh
395	57	LCC	33	62.5	8.1	48.95	1.39	10.6	Mo/Rh
396	48	LCC	33	72.6	8.1	57.84	1.62	12.3	Mo/Rh
397	57	LCC	33	80.2	8.1	53.4	1.79	13.6	Mo/Rh
398	51	RCC	33	89.8	8.1	57.84	2	15.2	Mo/Rh
399	53	LCC	33	89.9	8.1	66.75	2	15.3	Mo/Rh
400	50	LCC	33	91.5	8.1	53.4	2.04	15.5	Mo/Rh
401	50	RCC	33	100.6	8.1	75.65	2.24	17.1	Mo/Rh
402	51	LCC	33	106.6	8.1	57.84	2.37	18.1	Mo/Rh
403	44	RCC	33	116.6	8.1	48.95	2.6	19.8	Mo/Rh
404	47	LCC	33	61.3	8.2	53.4	1.35	10.4	Mo/Rh
405	52	LCC	33	77.6	8.2	53.4	1.71	13.2	Mo/Rh
406	53	RCC	33	81.8	8.2	48.95	1.81	13.9	Mo/Rh
407	49	LCC	33	89.7	8.2	53.4	1.98	15.3	Mo/Rh
408	48	RCC	33	93.1	8.2	62.29	2.06	15.9	Mo/Rh
409	47	RCC	33	84.4	8.2	66.75	2.14	14.4	Mo/Rh
410	48	LCC	33	97.1	8.2	57.84	2.14	16.5	Mo/Rh
411	58	LCC	33	110.9	8.2	48.95	2.45	18.9	Mo/Rh
412	49	LCC	33	124.7	8.2	62.29	2.75	21.2	Mo/Rh
413	58	RCC	33	131.1	8.2	48.95	2.89	22.3	Mo/Rh
414	46	LCC	33	65.1	8.3	71.19	1.42	11.1	Mo/Rh
415	59	RCC	33	69.1	8.3	57.84	1.51	11.8	Mo/Rh
416	58	LCC	33	73.3	8.3	71.19	1.6	12.5	Mo/Rh
417	52	LCC	33	84.3	8.3	53.4	1.84	14.4	Mo/Rh
418	56	RCC	33	84.2	8.3	84.55	1.84	14.4	Mo/Rh
419	43	LCC	33	85.9	8.3	57.84	1.88	14.7	Mo/Rh
420	60	RCC	33	110.9	8.3	44.5	2.43	19	Mo/Rh
421	47	LCC	33	173	8.3	71.19	3.79	29.6	Mo/Rh
422	49	RCC	33	54.9	8.4	66.75	1.19	9.42	Mo/Rh
423	59	LCC	33	67.7	8.4	53.4	1.47	11.6	Mo/Rh
424	59	LCC	33	97.1	8.4	62.29	2.11	16.7	Mo/Rh
425	58	LCC	33	99.1	8.4	66.75	2.15	17	Mo/Rh
426	53	LCC	33	111.5	8.4	62.29	2.42	19.1	Mo/Rh
427	50	RCC	33	118.2	8.4	66.75	2.56	20.3	Mo/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
428	52	LCC	33	36.9	8.5	53.4	0.79	6.36	Mo/Rh
429	57	RCC	33	71.1	8.5	44.5	1.53	12.2	Mo/Rh
430	50	RCC	33	77.6	8.5	57.84	1.67	13.4	Mo/Rh
431	59	RCC	33	85.8	8.5	57.84	1.85	14.8	Mo/Rh
432	47	LCC	33	111.6	8.5	53.4	2.4	19.2	Mo/Rh
433	45	RCC	33	122	8.5	62.29	2.62	21	Mo/Rh
434	58	LCC	33	126.3	8.5	53.4	2.72	21.8	Mo/Rh
435	45	RCC	33	136.5	8.5	66.75	2.94	23.5	Mo/Rh
436	58	RCC	33	105.6	8.6	66.75	2.25	18.3	Mo/Rh
437	53	RCC	33	107.7	8.6	75.65	2.3	18.6	Mo/Rh
438	44	RCC	33	119.8	8.6	57.84	2.56	20.7	Mo/Rh
439	44	LCC	33	229.4	8.6	62.29	4.89	39.7	Mo/Rh
440	47	RCC	33	69.1	8.7	53.4	1.46	12	Mo/Rh
441	57	RCC	33	106.8	8.7	53.4	2.26	18.5	Mo/Rh
442	53	LCC	33	117.3	8.7	66.75	2.48	20.4	Mo/Rh
443	47	RCC	33	123	8.7	71.19	2.6	21.3	Mo/Rh
444	55	RCC	33	138.8	8.7	44.5	2.94	24.1	Mo/Rh
445	46	RCC	33	82.9	8.8	80.09	1.74	14.4	Mo/Rh
446	50	LCC	33	90.5	8.8	66.75	1.9	15.8	Mo/Rh
447	43	RCC	33	108.4	8.8	62.29	2.27	18.9	Mo/Rh
448	49	LCC	33	76.9	8.9	62.29	1.6	13.4	Mo/Rh
449	57	LCC	33	101.1	8.9	48.95	2.11	17.7	Mo/Rh
450	49	LCC	34	65.2	9	71.19	1.48	12.4	Mo/Rh
451	50	RCC	34	105.2	9	89	2.39	20.1	Mo/Rh
452	44	RCC	34	199.7	9	66.75	4.55	38.1	Mo/Rh
453	56	RCC	34	81.8	9.1	71.19	1.85	15.7	Mo/Rh
454	57	RCC	34	88.9	9.1	71.19	2.01	17	Mo/Rh
455	41	RCC	34	101.3	9.1	84.55	2.29	19.4	Mo/Rh
456	53	RCC	34	104.4	9.1	66.75	2.36	20	Mo/Rh
457	45	LCC	34	126.1	9.1	62.29	2.85	24.1	Mo/Rh

Table II. The patient data underwent breast screening from tungsten target (425 data).

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
1	44	RCC	25	76.9	2.8	71.19	0.89	2.18	W/Rh
2	46	RCC	25	77.9	2.9	106.8	0.88	2.21	W/Rh
3	41	LCC	26	66.7	3.1	62.29	0.84	2.16	W/Rh
4	46	LCC	26	67.9	3.2	84.55	0.84	2.21	W/Rh
5	44	RCC	26	77.8	3.2	80.09	0.97	2.53	W/Rh
6	42	RCC	26	66.7	3.3	48.95	0.81	2.18	W/Rh
7	42	LCC	26	77	3.3	80.09	0.94	2.51	W/Rh
8	57	LCC	26	79	3.3	66.75	0.96	2.58	W/Rh
9	49	RCC	26	76	3.4	84.55	0.91	2.49	W/Rh
10	45	LCC	26	79.8	3.4	75.65	0.96	2.61	W/Rh
11	46	RCC	26	90.2	3.4	48.95	1.08	2.95	W/Rh
12	47	LCC	26	90	3.4	84.55	1.08	2.95	W/Rh
13	60	LCC	26	65.7	3.5	84.55	0.77	2.16	W/Rh
14	41	RCC	26	77.8	3.5	53.4	0.91	2.56	W/Rh
15	50	LCC	26	82.1	3.5	66.75	0.96	2.7	W/Rh
16	48	RCC	26	97	3.5	75.65	1.14	3.19	W/Rh
17	59	RCC	26	120.8	3.5	84.55	1.42	3.97	W/Rh
18	55	LCC	26	63.6	3.6	71.19	0.73	2.1	W/Rh
19	56	RCC	26	87.2	3.6	75.65	1	2.88	W/Rh
20	46	LCC	26	90.2	3.6	48.95	1.04	2.97	W/Rh
21	42	RCC	26	93	3.6	71.19	1.07	3.07	W/Rh
22	44	LCC	26	100	3.6	71.19	1.15	3.3	W/Rh
23	55	RCC	26	59.7	3.7	53.4	0.67	1.98	W/Rh
24	60	RCC	26	67.8	3.7	97.9	0.76	2.24	W/Rh
25	60	LCC	26	84	3.7	80.09	0.95	2.78	W/Rh
26	60	LCC	26	89	3.7	75.65	1	2.94	W/Rh
27	49	LCC	26	103.3	3.7	62.29	1.16	3.42	W/Rh
28	47	RCC	26	107.4	3.7	80.09	1.21	3.55	W/Rh
29	53	LCC	26	80	3.8	102.3	0.88	2.66	W/Rh
30	57	RCC	26	91.1	3.8	53.4	1.01	3.02	W/Rh
31	42	LCC	26	92.9	3.8	53.4	1.03	3.08	W/Rh
32	44	LCC	26	92.9	3.8	53.4	1.03	3.08	W/Rh
33	42	LCC	26	99.3	3.8	62.29	1.1	3.3	W/Rh
34	42	RCC	26	100.1	3.8	71.19	1.1	3.32	W/Rh
35	60	RCC	26	100.1	3.8	106.8	1.1	3.32	W/Rh
36	60	RCC	26	126.8	3.8	102.3	1.4	4.21	W/Rh
37	40	LCC	26	136.5	3.8	71.19	1.51	4.53	W/Rh
38	59	RCC	26	94.1	3.9	71.19	1.02	3.13	W/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
39	56	LCC	26	96.1	3.9	71.19	1.04	3.2	W/Rh
40	52	RCC	26	106.5	3.9	66.75	1.15	3.55	W/Rh
41	49	LCC	27	74.8	4	57.84	0.91	2.79	W/Rh
42	43	LCC	27	76	4	97.9	0.93	2.84	W/Rh
43	43	RCC	27	76.9	4	84.55	0.94	2.87	W/Rh
44	52	LCC	27	87.1	4	66.75	1.06	3.25	W/Rh
45	60	LCC	27	87.9	4	44.5	1.07	3.28	W/Rh
46	49	RCC	27	112.5	4	71.19	1.37	4.2	W/Rh
47	53	RCC	27	77.9	4.1	93.44	0.93	2.92	W/Rh
48	57	RCC	27	84.2	4.1	133.5	1.01	3.15	W/Rh
49	48	LCC	27	86	4.1	44.5	1.03	3.22	W/Rh
50	45	RCC	27	89.9	4.1	57.84	1.08	3.37	W/Rh
51	59	LCC	27	90.8	4.1	84.55	1.09	3.4	W/Rh
52	49	LCC	27	92.1	4.1	71.19	1.1	3.45	W/Rh
53	59	LCC	27	96.1	4.1	75.65	1.15	3.6	W/Rh
54	52	LCC	27	99.2	4.1	102.3	1.19	3.71	W/Rh
55	58	LCC	27	68.6	4.2	84.55	0.81	2.58	W/Rh
56	58	RCC	27	70.8	4.2	93.44	0.83	2.66	W/Rh
57	50	RCC	27	85.1	4.2	44.5	1	3.2	W/Rh
58	55	RCC	27	91	4.2	53.4	1.07	3.42	W/Rh
59	55	LCC	27	100.9	4.2	53.4	1.19	3.79	W/Rh
60	49	RCC	27	101.1	4.3	71.19	1.17	3.81	W/Rh
61	55	LCC	27	109.6	4.3	48.95	1.27	4.13	W/Rh
62	55	RCC	27	121.2	4.3	57.84	1.4	4.57	W/Rh
63	49	LCC	27	123.6	4.3	57.84	1.43	4.66	W/Rh
64	57	LCC	27	83.9	4.4	111.2	0.95	3.17	W/Rh
65	40	RCC	27	128.9	4.4	48.95	1.47	4.88	W/Rh
66	45	RCC	27	128.9	4.4	80.09	1.47	4.88	W/Rh
67	45	LCC	27	142.3	4.4	97.9	1.62	5.38	W/Rh
68	54	RCC	28	63.7	4.5	57.84	0.81	2.67	W/Rh
69	52	LCC	28	80.1	4.5	84.55	1.02	3.36	W/Rh
70	57	RCC	28	84	4.5	89	1.07	3.52	W/Rh
71	56	RCC	28	85.9	4.5	137.9	1.09	3.6	W/Rh
72	47	LCC	28	87.1	4.5	89	1.11	3.65	W/Rh
73	60	LCC	28	99.9	4.5	115.6	1.27	4.18	W/Rh
74	43	LCC	28	123.9	4.5	80.09	1.57	5.19	W/Rh
75	57	LCC	28	82.1	4.6	115.6	1.03	3.45	W/Rh
76	52	RCC	28	85.8	4.6	75.65	1.07	3.61	W/Rh
77	51	RCC	28	85.9	4.6	80.09	1.08	3.61	W/Rh
78	48	LCC	28	92.3	4.6	84.55	1.16	3.88	W/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
79	51	LCC	28	92.8	4.6	80.09	1.16	3.9	W/Rh
80	44	LCC	28	106.4	4.6	80.09	1.33	4.47	W/Rh
81	59	RCC	28	119.3	4.6	89	1.49	5.01	W/Rh
82	53	RCC	28	141.2	4.6	66.75	1.77	5.94	W/Rh
83	40	LCC	28	84.7	4.7	53.4	1.04	3.57	W/Rh
84	44	RCC	28	92.3	4.7	80.09	1.14	3.89	W/Rh
85	47	RCC	28	102.4	4.7	102.3	1.26	4.32	W/Rh
86	49	RCC	28	108.3	4.7	62.29	1.34	4.57	W/Rh
87	44	RCC	28	114.2	4.7	75.65	1.41	4.82	W/Rh
88	48	LCC	28	117	4.7	84.55	1.44	4.93	W/Rh
89	55	LCC	28	116.9	4.7	111.2	1.44	4.93	W/Rh
90	52	LCC	28	126.9	4.7	93.44	1.56	5.35	W/Rh
91	53	RCC	28	131.5	4.7	80.09	1.62	5.55	W/Rh
92	46	LCC	28	141.2	4.7	71.19	1.74	5.96	W/Rh
93	48	RCC	28	85.2	4.8	76.5	0.96	3.31	W/Rh
94	60	LCC	28	82.1	4.8	133.5	1	3.47	W/Rh
95	53	LCC	28	97	4.8	57.84	1.18	4.1	W/Rh
96	44	LCC	28	110	4.8	66.75	1.34	4.65	W/Rh
97	43	LCC	28	117.1	4.8	48.95	1.42	4.96	W/Rh
98	45	LCC	28	119.4	4.8	97.9	1.45	5.05	W/Rh
99	52	RCC	28	124.8	4.8	84.55	1.52	5.28	W/Rh
100	43	LCC	28	127.9	4.8	80.09	1.55	5.41	W/Rh
101	43	RCC	28	130.8	4.8	75.65	1.59	5.54	W/Rh
102	60	RCC	28	132.8	4.8	44.5	1.61	5.62	W/Rh
103	46	RCC	28	160.2	4.8	75.65	1.95	6.78	W/Rh
104	60	RCC	28	76.9	4.9	106.8	0.92	3.27	W/Rh
105	51	RCC	28	82.7	4.9	84.55	0.99	3.51	W/Rh
106	56	LCC	28	89.2	4.9	115.6	1.07	3.79	W/Rh
107	58	LCC	28	89.2	4.9	89	1.07	3.79	W/Rh
108	47	LCC	28	105.4	4.9	53.4	1.26	4.44	W/Rh
109	49	RCC	28	112	4.9	66.75	1.34	4.76	W/Rh
110	51	RCC	28	124.8	4.9	80.09	1.38	4.86	W/Rh
111	43	LCC	28	117	4.9	120.1	1.4	4.97	W/Rh
112	44	RCC	28	128.7	4.9	71.19	1.54	5.46	W/Rh
113	46	LCC	28	132.8	4.9	62.29	1.59	5.64	W/Rh
114	40	LCC	28	136.5	4.9	66.75	1.63	5.8	W/Rh
115	54	LCC	28	82	5	71.19	0.96	3.49	W/Rh
116	57	RCC	28	84.1	5	80.09	0.99	3.58	W/Rh
117	51	LCC	28	84.2	5	71.19	0.99	3.59	W/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
118	55	LCC	28	93.1	5	71.19	1.09	3.97	W/Rh
119	53	LCC	28	99.1	5	62.29	1.17	4.22	W/Rh
120	55	RCC	28	101.1	5	102.3	1.19	4.31	W/Rh
121	53	LCC	28	103	5	80.09	1.21	4.39	W/Rh
122	47	LCC	28	104.1	5	57.84	1.22	4.44	W/Rh
123	47	RCC	28	104.3	5	57.84	1.23	4.44	W/Rh
124	53	RCC	28	106.4	5	71.19	1.25	4.53	W/Rh
125	55	RCC	28	107.2	5	75.65	1.26	4.57	W/Rh
126	53	LCC	28	112.4	5	111.2	1.32	4.79	W/Rh
127	48	LCC	28	119.1	5	57.84	1.4	5.07	W/Rh
128	46	RCC	28	119.2	5	75.65	1.4	5.08	W/Rh
129	47	RCC	28	127.9	5	71.19	1.5	5.45	W/Rh
130	45	LCC	28	131.9	5	62.29	1.55	5.62	W/Rh
131	47	RCC	28	132.9	5	71.19	1.56	5.66	W/Rh
132	43	RCC	28	136.7	5	120.1	1.61	5.82	W/Rh
133	53	RCC	28	138.6	5	93.44	1.63	5.9	W/Rh
134	43	RCC	28	144.2	5	71.19	1.7	6.14	W/Rh
135	60	LCC	28	147.3	5	93.4	1.73	6.28	W/Rh
136	44	LCC	28	149.3	5	80.09	1.76	6.36	W/Rh
137	44	RCC	28	153.7	5	89	1.81	6.55	W/Rh
138	51	RCC	28	156.2	5	89	1.84	6.65	W/Rh
139	50	RCC	28	190.1	5	89	2.24	8.1	W/Rh
140	60	RCC	28	88.9	5.1	62.29	1.03	3.8	W/Rh
141	47	LCC	28	89.8	5.1	53.4	1.04	3.84	W/Rh
142	56	LCC	28	102.1	5.1	111.2	1.19	4.36	W/Rh
143	53	LCC	28	104.2	5.1	75.65	1.21	4.45	W/Rh
144	49	LCC	28	107.3	5.1	48.95	1.25	4.59	W/Rh
145	48	RCC	28	108.4	5.1	80.09	1.26	4.63	W/Rh
146	56	LCC	28	118.3	5.1	80.09	1.37	5.06	W/Rh
147	44	LCC	28	127.8	5.1	44.5	1.48	5.46	W/Rh
148	44	LCC	28	129.9	5.1	75.65	1.51	5.55	W/Rh
149	43	RCC	28	130.9	5.1	48.95	1.52	5.6	W/Rh
150	60	RCC	28	138.5	5.1	89	1.61	5.92	W/Rh
151	45	RCC	28	138.6	5.1	93.44	1.61	5.93	W/Rh
152	40	LCC	28	142.3	5.1	89	1.65	6.08	W/Rh
153	44	LCC	28	160.4	5.1	93.44	1.86	6.86	W/Rh
154	57	LCC	28	168.2	5.1	106.8	1.95	7.19	W/Rh
155	57	RCC	28	181.9	5.1	115.6	2.11	7.78	W/Rh
156	59	LCC	28	93	5.2	53.4	1.07	3.99	W/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
157	56	RCC	28	95.1	5.2	93.44	1.09	4.08	W/Rh
158	58	RCC	28	108.4	5.2	80.09	1.24	4.65	W/Rh
159	53	RCC	28	109.6	5.2	75.65	1.26	4.7	W/Rh
160	48	RCC	28	119.3	5.2	53.4	1.37	5.12	W/Rh
161	46	LCC	28	126.5	5.2	84.55	1.45	5.43	W/Rh
162	57	LCC	28	128.9	5.2	89	1.48	5.53	W/Rh
163	59	LCC	28	132.9	5.2	75.65	1.52	5.7	W/Rh
164	46	RCC	28	133.6	5.2	44.5	1.53	5.73	W/Rh
165	51	LCC	29	131.3	5.2	80.09	1.56	5.64	W/Rh
166	44	LCC	28	135.8	5.2	62.29	1.56	5.83	W/Rh
167	53	LCC	28	140.4	5.2	66.75	1.61	6.02	W/Rh
168	47	LCC	28	142.4	5.2	66.75	1.63	6.11	W/Rh
169	47	LCC	28	143.4	5.2	57.84	1.64	6.15	W/Rh
170	47	RCC	28	144.3	5.2	53.4	1.65	6.19	W/Rh
171	46	RCC	28	149.4	5.2	84.55	1.71	6.41	W/Rh
172	51	RCC	28	151.3	5.2	89	1.74	6.49	W/Rh
173	44	RCC	28	160.5	5.2	84.55	1.84	6.88	W/Rh
174	54	RCC	28	160.5	5.2	97.9	1.84	6.88	W/Rh
175	50	RCC	28	161.5	5.2	75.65	1.85	6.93	W/Rh
176	55	RCC	28	162.5	5.2	106.8	1.86	6.97	W/Rh
177	42	RCC	28	262.7	5.2	71.19	3.01	11.3	W/Rh
178	59	LCC	28	76.9	5.3	80.09	0.87	3.31	W/Rh
179	53	LCC	29	83.3	5.3	75.61	0.98	3.59	W/Rh
180	59	RCC	28	87.8	5.3	57.84	0.99	3.78	W/Rh
181	60	LCC	28	94.3	5.3	80.09	1.07	4.06	W/Rh
182	59	RCC	28	97.9	5.3	89	1.11	4.21	W/Rh
183	44	LCC	28	104.3	5.3	57.84	1.18	4.49	W/Rh
184	53	RCC	28	104.3	5.3	75.65	1.18	4.49	W/Rh
185	55	LCC	28	106.3	5.3	102.3	1.2	4.58	W/Rh
186	60	RCC	28	111.4	5.3	89	1.26	4.79	W/Rh
187	53	RCC	28	114.5	5.3	102.3	1.3	4.93	W/Rh
188	51	RCC	28	119.1	5.3	102.3	1.35	5.13	W/Rh
189	44	RCC	28	121.5	5.3	44.5	1.38	5.23	W/Rh
190	55	LCC	28	122.1	5.3	71.19	1.38	5.26	W/Rh
191	60	LCC	28	129.9	5.3	93.44	1.47	5.59	W/Rh
192	43	LCC	28	132.8	5.3	48.95	1.5	5.72	W/Rh
193	59	RCC	28	132.9	5.3	89	1.5	5.72	W/Rh
194	48	RCC	28	134.6	5.3	53.4	1.52	5.79	W/Rh
195	56	RCC	28	135.9	5.3	102.3	1.54	5.85	W/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
196	48	LCC	28	136.8	5.3	66.75	1.55	5.89	W/Rh
197	52	LCC	28	148.7	5.3	111.2	1.68	6.4	W/Rh
198	59	LCC	28	151	5.3	93	1.71	6.5	W/Rh
199	40	RCC	28	155	5.3	75.65	1.75	6.67	W/Rh
200	48	RCC	28	160.6	5.3	80.09	1.82	6.91	W/Rh
201	42	LCC	28	206.2	5.3	44.5	2.33	8.88	W/Rh
202	54	RCC	28	82	5.4	62.29	0.92	3.54	W/Rh
203	40	RCC	28	102.1	5.4	53.4	1.14	4.41	W/Rh
204	57	LCC	28	106.3	5.4	137.9	1.19	4.59	W/Rh
205	56	LCC	28	122.1	5.4	89	1.36	5.27	W/Rh
206	56	RCC	28	125.8	5.4	62.29	1.41	5.43	W/Rh
207	54	LCC	28	137.7	5.4	80.09	1.54	5.95	W/Rh
208	55	RCC	28	139.6	5.4	75.65	1.56	6.03	W/Rh
209	47	RCC	28	149.3	5.4	57.84	1.67	6.45	W/Rh
210	40	RCC	28	162.4	5.4	71.19	1.81	7.01	W/Rh
211	42	LCC	28	167.4	5.4	84.55	1.87	7.23	W/Rh
212	50	LCC	28	172.4	5.4	80.09	1.93	7.45	W/Rh
213	50	RCC	28	181.3	5.4	89	2.03	7.83	W/Rh
214	56	LCC	29	92.1	5.5	53.4	1.14	4.36	W/Rh
215	60	RCC	29	110.4	5.5	57.84	1.37	5.23	W/Rh
216	59	LCC	29	111.4	5.5	62.29	1.38	5.28	W/Rh
217	58	LCC	29	113.3	5.5	129	1.41	5.37	W/Rh
218	49	LCC	29	116.3	5.5	57.84	1.44	5.51	W/Rh
219	53	LCC	29	116.3	5.5	93.44	1.44	5.51	W/Rh
220	55	RCC	29	116.9	5.5	80.09	1.45	5.54	W/Rh
221	50	LCC	29	119	5.5	84.55	1.48	5.64	W/Rh
222	48	LCC	29	123.7	5.5	71.19	1.54	5.86	W/Rh
223	48	RCC	29	126.5	5.5	80.09	1.57	5.99	W/Rh
224	55	LCC	29	132.9	5.5	75.65	1.65	6.3	W/Rh
225	52	RCC	29	136.4	5.5	93.44	1.69	6.46	W/Rh
226	46	LCC	29	137.7	5.5	71.19	1.71	6.52	W/Rh
227	40	LCC	29	140.5	5.5	66.75	1.74	6.66	W/Rh
228	51	LCC	29	142.3	5.5	62.29	1.77	6.74	W/Rh
229	52	LCC	29	144.2	5.5	75.65	1.79	6.83	W/Rh
230	58	RCC	29	148.7	5.5	84.55	1.85	7.05	W/Rh
231	48	LCC	29	149.3	5.5	66.75	1.85	7.07	W/Rh
232	40	RCC	29	151.1	5.5	62.29	1.88	7.16	W/Rh
233	45	LCC	29	163.5	5.5	53.4	2.03	7.75	W/Rh
234	48	LCC	29	175.5	5.5	66.75	2.18	8.31	W/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
235	53	RCC	29	188.1	5.5	102.3	2.34	8.91	W/Rh
236	56	RCC	29	90	5.6	44.5	1.1	4.28	W/Rh
237	47	RCC	29	92.1	5.6	44.5	1.13	4.38	W/Rh
238	54	RCC	29	99.2	5.6	66.75	1.21	4.72	W/Rh
239	60	LCC	29	102.9	5.6	89	1.26	4.89	W/Rh
240	56	LCC	29	108.3	5.6	75.65	1.33	5.15	W/Rh
241	55	RCC	29	110.5	5.6	142.3	1.35	5.25	W/Rh
242	50	RCC	29	112.6	5.6	84.55	1.38	5.35	W/Rh
243	47	LCC	29	117	5.6	62.29	1.43	5.56	W/Rh
244	44	LCC	29	120.1	5.6	48.95	1.47	5.71	W/Rh
245	47	RCC	29	123.7	5.6	71.19	1.51	5.88	W/Rh
246	57	RCC	29	123.7	5.6	44.5	1.51	5.88	W/Rh
247	43	RCC	29	125.9	5.6	84.55	1.54	5.99	W/Rh
248	49	LCC	29	128.9	5.6	66.75	1.58	6.13	W/Rh
249	44	RCC	29	139.7	5.6	75.65	1.71	6.64	W/Rh
250	43	RCC	29	142.4	5.6	44.5	1.74	6.77	W/Rh
251	53	LCC	29	146.1	5.6	84.55	1.79	6.95	W/Rh
252	58	LCC	29	146.2	5.6	102.3	1.79	6.95	W/Rh
253	48	LCC	29	197.5	5.6	62.29	2.42	9.39	W/Rh
254	54	LCC	29	202	5.6	57.84	2.47	9.6	W/Rh
255	46	LCC	29	213.7	5.6	106.8	2.62	10.2	W/Rh
256	54	RCC	29	84.9	5.7	48.95	1.03	4.05	W/Rh
257	41	LCC	29	98	5.7	62.29	1.18	4.67	W/Rh
258	53	RCC	29	104.3	5.7	80.09	1.26	4.98	W/Rh
259	51	LCC	29	105.3	5.7	75.65	1.27	5.02	W/Rh
260	57	RCC	30	107	5.7	104.08	1.32	5.07	W/Rh
261	47	LCC	29	115.1	5.7	84.55	1.39	5.49	W/Rh
262	52	LCC	29	134.8	5.7	111.2	1.63	6.43	W/Rh
263	45	RCC	29	137.8	5.7	62.29	1.66	6.57	W/Rh
264	59	RCC	29	137.8	5.7	80.09	1.66	6.57	W/Rh
265	57	RCC	29	141.4	5.7	84.55	1.71	6.75	W/Rh
266	46	LCC	29	147.3	5.7	75.65	1.78	7.03	W/Rh
267	47	RCC	29	151.4	5.7	97.9	1.83	7.22	W/Rh
268	50	LCC	29	162.6	5.7	57.84	1.96	7.76	W/Rh
269	47	LCC	29	168.2	5.7	53.4	2.03	8.02	W/Rh
270	42	RCC	29	176.1	5.7	93.44	2.13	8.4	W/Rh
271	48	LCC	29	219.1	5.7	80.09	2.65	10.5	W/Rh
272	57	LCC	30	81.2	5.8	81.4	0.99	3.86	W/Rh
273	57	RCC	29	95.9	5.8	106.8	1.14	4.59	W/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
274	56	LCC	29	99.2	5.8	93.44	1.18	4.75	W/Rh
275	48	LCC	29	99.9	5.8	66.75	1.19	4.78	W/Rh
276	55	LCC	29	104.5	5.8	93.44	1.24	5	W/Rh
277	57	LCC	29	107.5	5.8	84.55	1.28	5.15	W/Rh
278	58	RCC	29	113.3	5.8	75.65	1.35	5.42	W/Rh
279	60	RCC	29	118.3	5.8	71.19	1.41	5.66	W/Rh
280	57	LCC	29	131.9	5.8	44.5	1.57	6.31	W/Rh
281	43	RCC	29	135.8	5.8	62.29	1.62	6.5	W/Rh
282	60	RCC	29	140.4	5.8	93.44	1.67	6.72	W/Rh
283	43	LCC	29	147.4	5.8	120	1.75	7.06	W/Rh
284	42	LCC	29	153.1	5.8	97.9	1.82	7.33	W/Rh
285	53	LCC	29	153.1	5.8	62.29	1.82	7.33	W/Rh
286	47	LCC	29	167.3	5.8	75.65	1.99	8.01	W/Rh
287	52	LCC	29	174.2	5.8	71.19	2.07	8.34	W/Rh
288	45	RCC	29	188.1	5.8	57.84	2.24	9	W/Rh
289	50	LCC	29	193.7	5.8	102.3	2.31	9.27	W/Rh
290	45	RCC	29	193.8	5.8	80.09	2.31	9.28	W/Rh
291	46	LCC	29	224.7	5.8	84.55	2.67	10.8	W/Rh
292	53	LCC	29	238.4	5.8	133.5	2.84	11.4	W/Rh
293	50	LCC	29	253	5.8	93.44	3.01	12.1	W/Rh
294	53	LCC	30	109.6	5.81	57.84	1.35	5.81	W/Rh
295	54	LCC	29	87.8	5.9	48.95	1.03	4.22	W/Rh
296	54	LCC	29	100.1	5.9	57.84	1.17	4.81	W/Rh
297	56	LCC	29	101.1	5.9	66.75	1.19	4.86	W/Rh
298	52	RCC	29	103	5.9	57.84	1.21	4.95	W/Rh
299	53	LCC	29	103	5.9	71.19	1.21	4.95	W/Rh
300	53	LCC	29	105.2	5.9	75.65	1.23	5.05	W/Rh
301	56	RCC	29	107.5	5.9	111.2	1.26	5.16	W/Rh
302	51	LCC	29	108.3	5.9	48.95	1.27	5.2	W/Rh
303	56	RCC	29	109.5	5.9	102.3	1.28	5.26	W/Rh
304	56	RCC	29	111.5	5.9	75.65	1.31	5.36	W/Rh
305	56	RCC	29	112.5	5.9	89	1.32	5.4	W/Rh
306	47	LCC	29	116.9	5.9	53.4	1.37	5.61	W/Rh
307	47	RCC	29	122.1	5.9	84.55	1.43	5.86	W/Rh
308	60	LCC	29	125.9	5.9	53.4	1.48	6.05	W/Rh
309	45	LCC	29	132.8	5.9	120.1	1.56	6.38	W/Rh
310	50	RCC	29	132.9	5.9	57.84	1.56	6.38	W/Rh
311	53	RCC	29	147.3	5.9	93.44	1.73	7.08	W/Rh
312	48	RCC	29	151.3	5.9	71.19	1.78	7.27	W/Rh

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
313	53	RCC	29	151.5	5.9	66.75	1.78	7.28	W/Rh
314	43	LCC	29	163.4	5.9	93.44	1.92	7.85	W/Rh
315	50	LCC	29	170.1	5.9	75.65	2	8.17	W/Rh
316	52	RCC	29	179.1	5.9	71.19	2.1	8.6	W/Rh
317	45	LCC	29	183	5.9	71.19	2.15	8.79	W/Rh
318	44	LCC	29	200.5	5.9	80.09	2.35	9.63	W/Rh
319	45	RCC	29	215.6	5.9	80.09	2.53	10.4	W/Rh
320	47	LCC	29	233.6	5.9	62.29	2.74	11.2	W/Rh
321	58	RCC	28	115.2	7	44.5	1.3	5.86	W/Ag
322	54	LCC	28	125.9	7	93.44	1.42	6.4	W/Ag
323	56	RCC	28	129.9	7	62.29	1.46	6.61	W/Ag
324	58	RCC	28	136	7	66.75	1.53	6.92	W/Ag
325	56	LCC	28	147.3	7	57.84	1.66	7.49	W/Ag
326	42	RCC	28	148.7	7	75.65	1.67	7.56	W/Ag
327	49	RCC	28	159.2	7	48.95	1.79	8.1	W/Ag
328	54	LCC	28	179.3	7	62.29	2.02	9.12	W/Ag
329	41	RCC	28	208.3	7	75.65	2.34	10.6	W/Ag
330	42	RCC	28	228.5	7	75.65	2.57	11.6	W/Ag
331	47	RCC	28	251.1	7	53.4	2.82	12.8	W/Ag
332	58	LCC	28	102.2	7.1	48.95	1.14	5.22	W/Ag
333	56	LCC	28	115.2	7.1	48.95	1.28	5.88	W/Ag
334	56	RCC	28	118.2	7.1	48.95	1.32	6.03	W/Ag
335	48	LCC	28	134.9	7.1	62.29	1.5	6.88	W/Ag
336	60	LCC	28	135.9	7.1	62.29	1.51	6.94	W/Ag
337	55	LCC	28	137.8	7.1	75.65	1.54	7.03	W/Ag
338	48	RCC	28	138.4	7.1	84.55	1.54	7.06	W/Ag
339	52	LCC	28	143.5	7.1	66.75	1.6	7.32	W/Ag
340	42	LCC	30	122.9	7.1	89.85	1.77	7.8	W/Ag
341	44	LCC	28	168.2	7.1	44.5	1.87	8.58	W/Ag
342	59	RCC	28	173.7	7.1	71.19	1.94	8.86	W/Ag
343	50	LCC	28	183.1	7.1	57.84	2.04	9.34	W/Ag
344	44	RCC	28	193	7.1	44.5	2.15	9.85	W/Ag
345	51	LCC	28	204.5	7.1	62.29	2.28	10.4	W/Ag
346	58	LCC	28	118.3	7.2	66.75	1.31	6.06	W/Ag
347	48	LCC	28	121.2	7.2	66.75	1.34	6.21	W/Ag
348	59	LCC	28	151.3	7.2	111.2	1.67	7.75	W/Ag
349	54	LCC	28	153.2	7.2	57.84	1.69	7.85	W/Ag
350	46	RCC	28	156.2	7.2	53.4	1.72	8	W/Ag
351	43	RCC	28	157.3	7.2	97.9	1.74	8.06	W/Ag

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
352	55	LCC	28	171.3	7.2	120.1	1.89	8.77	W/Ag
353	52	RCC	28	188.6	7.2	53.4	2.08	9.66	W/Ag
354	49	LCC	28	192.1	7.2	62.29	2.12	9.84	W/Ag
355	54	RCC	28	247.2	7.2	44.5	2.73	12.7	W/Ag
356	50	LCC	28	121.1	7.3	44.5	1.32	6.22	W/Ag
357	55	LCC	28	138.5	7.3	106.8	1.52	7.12	W/Ag
358	47	LCC	28	140.5	7.3	84.55	1.54	7.22	W/Ag
359	52	LCC	28	148.7	7.3	66.75	1.63	7.64	W/Ag
360	52	RCC	28	151.1	7.3	75.65	1.65	7.77	W/Ag
361	51	LCC	28	155.1	7.3	62.29	1.7	7.97	W/Ag
362	52	RCC	28	167.4	7.3	84.55	1.83	8.6	W/Ag
363	54	RCC	28	170.1	7.3	89	1.86	8.74	W/Ag
364	48	RCC	28	175.5	7.3	71.19	1.92	9.02	W/Ag
365	48	LCC	28	193	7.3	57.84	2.11	9.92	W/Ag
366	48	LCC	28	216.3	7.3	129	2.37	11.1	W/Ag
367	45	RCC	28	241.2	7.3	84.55	2.64	12.4	W/Ag
368	54	RCC	28	124.4	7.4	44.5	1.35	6.42	W/Ag
369	58	RCC	28	127.8	7.4	62.29	1.38	6.59	W/Ag
370	48	RCC	28	128.9	7.4	75.65	1.4	6.65	W/Ag
371	56	LCC	28	138.6	7.4	57.84	1.5	7.15	W/Ag
372	56	LCC	28	144.2	7.4	53.4	1.56	7.44	W/Ag
373	42	RCC	28	145.4	7.4	71.19	1.58	7.5	W/Ag
374	55	RCC	28	145.4	7.4	75.65	1.58	7.5	W/Ag
375	58	RCC	29	104.3	7.5	62.29	1.28	5.95	W/Ag
376	59	LCC	29	115.2	7.5	53.4	1.42	6.57	W/Ag
377	52	LCC	29	121.1	7.5	57.84	1.49	6.91	W/Ag
378	50	RCC	29	126.5	7.5	57.84	1.56	7.22	W/Ag
379	54	RCC	29	135.8	7.5	66.75	1.67	7.75	W/Ag
380	43	LCC	29	139.7	7.5	80.09	1.72	7.97	W/Ag
381	55	RCC	29	142.3	7.5	44.5	1.75	8.12	W/Ag
382	54	LCC	29	156.2	7.5	115.6	1.92	8.91	W/Ag
383	40	LCC	29	185.2	7.5	48.95	2.28	10.6	W/Ag
384	46	RCC	29	211.8	7.5	48.95	2.6	12.1	W/Ag
385	45	LCC	29	330.2	7.5	57.84	4.06	18.8	W/Ag
386	59	RCC	29	123.7	7.6	53.4	1.51	7.08	W/Ag
387	42	LCC	29	131.7	7.6	62.29	1.6	7.54	W/Ag
388	50	LCC	29	144.3	7.6	57.84	1.76	8.26	W/Ag
389	55	RCC	29	167.3	7.6	106.8	2.04	9.58	W/Ag
390	52	LCC	29	186.7	7.6	66.75	2.27	10.7	W/Ag

Number of patient	Age (Y)	Position	kVp	mAs	CBT (cm)	CPF (N)	AGD (mGy)	ESAK (mGy)	Target/Filter
391	42	RCC	31	162.3	7.6	68.5	2.49	11.36	W/Ag
392	48	RCC	29	215.7	7.6	62.29	2.63	12.4	W/Ag
393	49	RCC	29	222.8	7.6	71.19	2.71	12.8	W/Ag
394	49	LCC	29	231.3	7.6	66.75	2.82	13.2	W/Ag
395	60	LCC	29	120.1	7.7	48.95	1.45	6.9	W/Ag
396	60	LCC	29	121.1	7.7	48.95	1.46	6.96	W/Ag
397	53	LCC	29	131.7	7.7	44.5	1.59	7.57	W/Ag
398	51	LCC	29	137.5	7.7	97.9	1.66	7.9	W/Ag
399	53	RCC	29	139.6	7.7	44.5	1.68	8.02	W/Ag
400	46	LCC	29	140.4	7.7	53.4	1.69	8.07	W/Ag
401	47	RCC	29	145.3	7.7	80.09	1.75	8.35	W/Ag
402	52	LCC	29	151.1	7.7	48.95	1.82	8.68	W/Ag
403	42	LCC	29	232.7	7.7	66.75	2.81	13.4	W/Ag
404	58	LCC	29	135.9	7.8	62.29	1.62	7.84	W/Ag
405	55	LCC	29	158.4	7.8	44.5	1.89	9.14	W/Ag
406	48	RCC	29	197.5	7.8	102.3	2.36	11.4	W/Ag
407	53	RCC	29	145.4	7.9	44.5	1.72	8.42	W/Ag
408	41	RCC	29	153.8	7.9	75.65	1.82	8.9	W/Ag
409	60	RCC	29	155	7.9	53.4	1.83	8.97	W/Ag
410	59	LCC	29	167.4	7.9	44.5	1.98	9.69	W/Ag
411	59	RCC	29	177	7.9	44.5	2.09	10.2	W/Ag
412	60	RCC	30	127.7	8	44.5	1.69	8.1	W/Ag
413	56	RCC	30	164.3	8	62.29	2.17	10.4	W/Ag
414	45	LCC	30	200.7	8	71.19	2.65	12.7	W/Ag
415	48	RCC	30	112.5	8.1	44.5	1.47	7.16	W/Ag
416	51	RCC	30	131.9	8.1	111.2	1.73	8.4	W/Ag
417	53	LCC	30	142.4	8.2	53.4	1.85	9.1	W/Ag
418	55	RCC	30	129.8	8.3	71.19	1.67	8.32	W/Ag
419	50	RCC	30	145.4	8.3	62.29	1.88	9.32	W/Ag
420	41	LCC	30	147.4	8.4	57.84	1.89	9.49	W/Ag
421	55	LCC	31	134.8	8.8	66.75	1.87	9.54	W/Ag
422	49	RCC	31	270	8.8	89	3.74	19.1	W/Ag
423	55	RCC	31	137.8	8.9	57.84	1.89	9.79	W/Ag
424	55	LCC	32	99	9	71.19	1.49	7.6	W/Ag
425	50	LCC	32	128.9	9.1	44.5	1.95	9.93	W/Ag

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