Sudan University of Science &Technology

College of Graduate Studies

Assessment of Quality Control of X-ray Mammography Machine in Alnilain Medical Center& Royal Care Hospital

تقييم ضبط الجودة لجهاز تصويرالثدي بالاشعة السينية في مركز النيلين الطبي و مستشفى رويال كير

Thesis submitted in partial Fulfillment for the Requirements of

M.Sc in medical physics

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الآيــة

بِسْمِ اللهِ الرَّحْمَنِ الرَّحِيمِ

قال تعالى:

{وَ قُـل رَبِّ زِدنِي عِلماً}

سورة طة الأية 114

صدق الله العظيم

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!I would first like to thank my thesis supervisor Dr. salah Alli Fadlalla who gave me much of his time for careful supervision, cooperation and advice during this period.

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Dedication

I would like to express my profound gratitude to the puresoul of my father and for my beloved mother. I also dedicate this study to my all sisters and brothers and to my husband for providing me with endless support and continuous encouragement through the process of researching and writing this thesis. This accomplishment would not have been possible without them, but before all, the real praises and gratitude are extended to Allah the Almighty.

Abstract

A systematic approach for assessing critical performance indicators can be achieved through the implementation of a quality assurance (QA) program.

The objective of this study was to evaluate the quality control of x-ray mammography machine in two centers, namely: during the period from October to December 2017.

The test results were done by quality control tools and image quality tools.

Series of tests(specific radiation output, output variation with kVp, output variation with mAs, half value layer, mean glandular dose, image quality evaluation) were done using different tools (Semiconductor detector ,AL sheets (0.1 mm thickness) PMMA thickness, image quality tools(TORMAM,TORMAX)).

All the results from the two centers were compatible with the international standards values.

The study proposed some recommendations which could be useful in this field if applied properly. Future studies in this field should include other QC tests on more clinical centers to guarantee more reliable results.

ملخص البحث

هناك طريقه منتظمه لتحديد مؤشرات الاداء يمكن تحقيقها عن طريق برنامج تاكيد الجودة.

الهدف الاساسي من هذه الدراسه هو تقويم ضبط الجودة لجهاز الاشعه السينيه لتصويرالثدي في مركزين من المراكز الطبيه هي مركز النيلين التشخيصي الطبي ومستشفي رويال كيرفي الفتره من اكتوبرالي ديسمبر2017.

تم إجراء مجموعه من الاختبارات و الحصول علي نتائج، اشتملت علي: خرج الاشعاع المحدد من خلال قياس (الكيرما)، واختلافات الخرج حسب تغير قيمة الفولتيه المستخدمه مع إستخدام تيار كهربي و زمن ثابت، إيضا إختلاف الخرج عند تغيير قيمة التيار الكهربي والزمن المستخدم و ثبات الفولتيه، بالإضافه الي الطبقة المنصفه للقيمة،و متوسط الجرعة الغديه.ايضا تم تقييم جوده الصورة من خلال تصوير اجسام مكافئه للانسجه.

تم إجراء جميع هذه الاختبارات باستخدام ادوات مختلفه: كواشف شبه الموصلهوشرائح الالمونيومبسمك 0.1 مليمتر وسماكات من الادوات التماثليه (فانتوم) و تصويرالاجسام المكافئه للانسجه (تورماكس, تورمام) لتقييم جوده الصوره.كانت جميع النتائج في المركزين تحت الدراسه منسجمه مع المعايير الدوليه.

اقترحت الدراسه بعض التوصيات التي يمكن ان تكون مفيده في هذا المجال اذا طبقت بالطريقة المثلي.

ينبغي لاي دراسه مستقبليه في هذاالمجال ان تشتمل علي عدداكبرمن المراكزالطبيه واختبارات ضبط جوده اخري حتي يتم الحصول علي نتائج اكثر إعتماديه.

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List of Abbreviations

ACR	American College of Radiology
MQSA	Mammography Quality Standards Act
FDA	Food and Drug Administration
QA	Quality Assurance
QC	Quality control
AEC	Automatic Exposure Control
CR	Computed Radiography
DR	Digital Radiography
KVp:	kilovoltage peak
mAs:	milli Ampere second
HVL	Half Value layer
IAEA:	International Atomic Energy Agency
ICRP:	International Commission on Radiation Protection
MGD	mean Glandular Dose
Mr	Milli Roentgen
OD	Optical density
PMMA	Poly methyl methacrylate
SID	Source Image Distance

Chapter one

Introduction

Chapter One

Introduction

1.1 Definition of mammography:

Mammography is an x-ray imaging procedure for examining the breast. It is used primarily for the detection and diagnosis of breast cancer, but also for the guidance of needle biopsies and pre-surgical localization of suspicious areas.
Earlier detection has contributed to reduction of mortality from breast Cancer. To realize the benefits of mammography it must be carried out on high-quality equipment that is properly maintained and calibrated. The examinations must be performed by well-trained radiographers and interpreted by skilled radiologists with specialized experience in mammography. (Inokuti, 2009)

1.1.1 Breast Cancer:

Internationally, breast cancer has been the cancer of highest incidence and mortality in women. More than 1 million were diagnosed with breast cancer internationally in 2002 with more than 477,000 deaths .The cause or causes of breast cancer are not completely understood; however, it has been demonstrated that mortality is substantially reduced if disease is detected at an early stage (Inokuti, 2009).
The radiological signs of breast cancer include mass densities that are typically slightly more attenuating of X rays than the surrounding normal tissue, small microcalcifications, asymmetry between the two breasts and architectural distortion of tissue patterns. To detect breast cancer accurately and at the earliest possible stage, the image must have excellent contrast to reveal mass densities and spiculated fibrous structures radiating from them, which are characteristic of cancer. In addition, the spatial resolution must be excellent to reveal the calcifications, their number and their shape. The imaging system must have

adequate latitude to provide this contrast and resolution over the entire breast effectively. The geometrical characteristics of the x ray unit and the positioning of the breast by the radiographer must be such that as much breast tissue as possible is included in the mammogram.

Finally, the noise (signal fluctuation) of the image must be sufficiently low to reveal the subtle structures in a reliable manner, and the x ray dose must be as low as is reasonably achievable while being compatible with these image quality requirements.(IEAE, 2011)

1.1.2 Quality Control (QC):

A structured quality control program must be employed to monitor the performance of mammography equipment and to provide a record in case of machine failure.

The procedures must be performed regularly and require careful, consistent record keeping and regular comparison with baseline measurements obtained during acceptance testing.

When problems are noted, appropriate remedial action must be taken with subsequent testing to verify correction of the problem (Marline, 1990).

1.2 Problem of the study:

There are many problems due to absence of the quality control program at the two medical centers under study to the best of the researcher knowledge, which is necessary to improve the quality of radiographs and reduce radiation exposure to patients and staff.

1.3 Objectives of the study:

1.3.1 General objective:

To evaluate the quality control of x-ray mammography machine in Alnilain Medical Center& Royal Care Hospital.

1.3.2 Specific objectives:

. To measure air kerma and calculate MGD.

. To measure different parameters (Kvp, mAs, HVL)

.To evaluate the machines performance.

.To compare the results with the international standards.

. To evaluate the image quality.

1.4 Significance of the study:

Absence of quality control of x-ray mammography can lead to wrong diagnosis, and regular QC program can assist in preventing the faults and lead to correct diagnosis.

1.5 Thesis outlines:

This thesis will be contained in five chapters:

Chapter one is introduction with theoretical frame work of the study presents the statement of the study problems, objectives of the study , Chapter tow is Literature Review, Chapter three is Materials and method, Chapter four Results, Chapter five discussion, conclusion, recommendations and references.

Chapter two

Literature Review

Chapter two

Literature Review

2.1 Theoretical background

2.1.1. Anatomy and Physiology of the Breast:

The mammogram must accurately represent the anatomy of the breast, illustrated in Figure 2.1. The breast is a compound exocrine-modified sweat gland that rests on the pectoralis muscle of the anterior chest wall. It can extend from the midaxillaryline laterally to the sternum medially and from the second to the sixth costal cartilage. The basic structure of the breast is the lobe that drains by the lactiferous duct opening onto the nipple. Within each lobe there are multiple lobules. The terminal ductal lobular unit is the site of origin of most breast disease and is normally only about 3 mm to 5 mm in size. It consists of the extralobularterminal duct and the lobule. The latter is comprised of the intralobular terminal duct and the acini. The arterial supply is primarily from the lateral thoracic and intercostal arteries with branches from the internal mammary arter. The lymphatic system is the route of spread of breast cancer to other parts of the body. The lymphatic vessels drain primarily to the axillary, interpectoral, supraclavicular, and internal mammary nodes. However, there is also free communication to the opposite breast and into the abdomen (Inokuti, 2009).

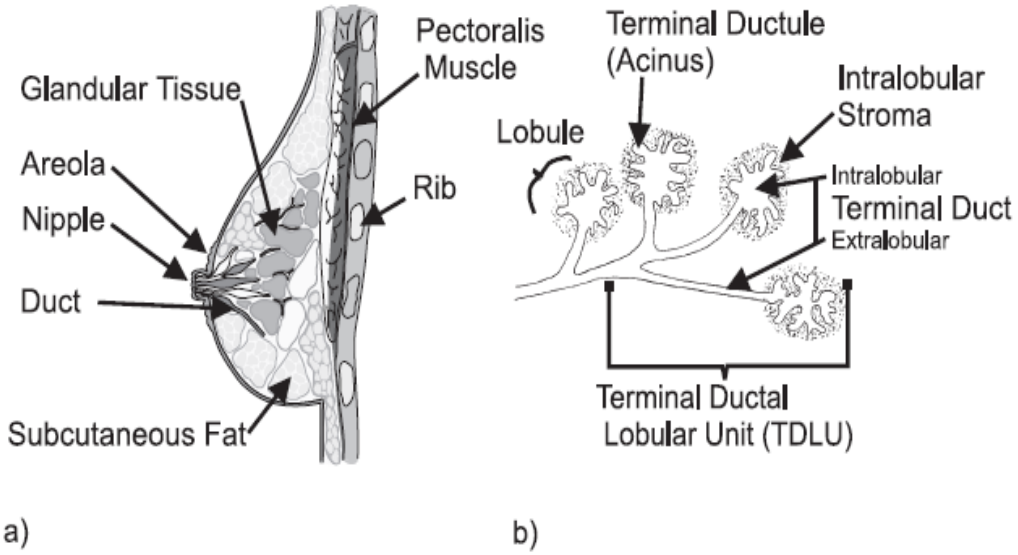


Figure 2.1: schematic anatomy of the breast a, lateral view b, terminal ductal lobular unit (Michael Fitzpatrics, 2000).

2.1.2. Mammography:

Early x-ray mammography was performed with direct exposure film (intensifying screen were not used), required high radiation dose, and produced images of low contrast and poor diagnostic quality. Mammography using the xeroradiographic process was very popular in the 1970s and early 1980s, spurred by high spatial resolution and edge-enhanced images; however, it's relatively poor sensitivity for breast masses and higher radiation dose compared to screen-film mammography led to its demise in the late 1980s continuing refinements in screen-film technology and digital mammography, which entered the clinical arena in the early 2000s, further improved mammography.

The American Collage of Radiation (ACR) mammography accreditation program changed the practice of mammography in the mid-1980, with recommendations

For minimum standards of practice and quality control (QC) that spurred

Improvements in technology and ensured quality of service. The federal Mammography Quality Standards Act (MQSA) was enacted in 1992. The law

and associated federal regulations issued by the US Food and Drug Administration (FDA), made many of the standards of the accreditation program mandatory. For digital mammography systems, many of the regulatory requirements entail following the manufacturer's recommended QC procedures.
Breast cancer screening programs depend on x-ray mammography because it is a low-cost, low–radiation dose procedure that has the sensitivity to detect early-stage breast cancer. Mammographic features characteristic of breast cancer are masses, particularly ones with irregular or "spiculated" margins; clusters of microcalcifications; and architectural distortions of breast structures (Jerrold, 2011).
Recall that higher energy x-rays are more penetrating, but lower energy x-rays give better contrast between different tissues. Thus, although using lower energy x-rays increases the dose, it improves contrast. This is especially important in mammography, where the radiologists seek inherently low contrast structures. In part this is because the x-ray absorptions of different types of soft tissue are all very similar. Breast tumors do not absorb x-rays appreciably differently from breast gland tissue, so their subject contrast is inherently poor; better contrast occurs when the tumor is surrounded by fat, which is somewhat less absorbing than glandular tissue at low energies (Suzanne, 2009).

2.1.3Interaction of X- ray in mammography

Radiologists use X-rays to produce medical images of the human body. Firstly X-rays are produced in an X-ray tube, the cathode provides a supply of electrons; these electrons strike the anode causing them to decelerate rapidly. The electrons interact with the target atoms in the anode and X-rays are produced (Conell, 2004).

When X-rays pass through a human body several interactions can occur; Elastic scattering, the photoelectric effect and Compton scattering. Elastic scattering occurs when an electron takes up energies of vibration when they pass close to

an atom. Only a certain amount of elastic scattering occurs at all X-ray energies and it never counts for more than 10% of the total interaction process in diagnostic radiology.

The photoelectric effect is the most important interaction, from a diagnostic point of view, between X-rays and bound electrons. In this process the incoming photon is completely absorbed and an electron is dislodged from its orbit around a nucleus. The photoelectric effect depends on the atomic mass Z of the tissue it passes through. In mammography soft tissue and cancerous tissue are very similar but their atomic number differs, therefore the photoelectric effect is the most important interaction in mammography.

The Compton Effect involves the interaction with unbound electrons. It is also known as inelastic scattering. It is the most important effect in radiology that involves unbound electrons. The photons interact with unbound electrons in a billiard ball type collision (Conell, 2004).

The morphological differences between normal and cancerous tissues in the breast and the presence of microcalcifications require the use of x-ray equipment designed specifically to optimize breast cancer detection. As shown in Figure (2.2) A the attenuation differences between normal and cancerous tissue are extremely small. Subject contrast, shown in Figure (2.2) B is highest at low x-ray energies (10 to 15 keV) and reduced higher energies (e.g., greater than 30 keV).

(Jerrold et al, 2011).

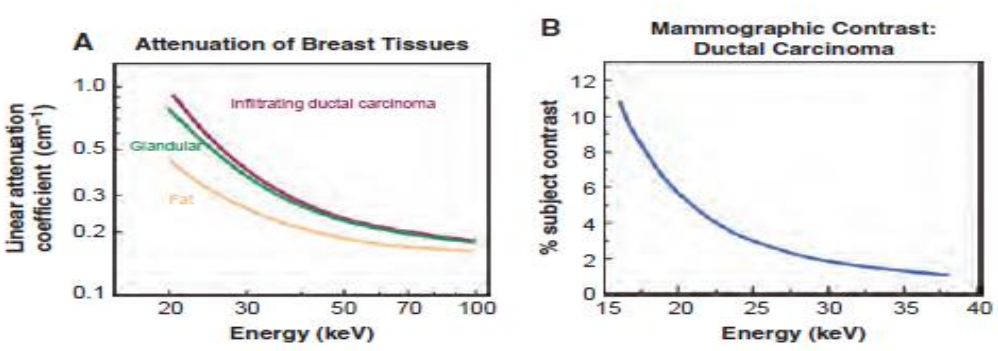


Figure (2.2) A. Attenuation of breast tissues. **Figure(2.2) B.** Calculated percentage contrast of the ductal carcinoma (Jerrold, 2011)

2.1.4 Types of mammography units:

Mammography units are used exclusively for X-ray exams of the breast, with special accessories that allow only the breast to be exposed to the x Rays. There are two types of units, digital and analogue mammography.

The patient examination is the same with both types, but the processing and management of images differ (PAHO, 2016).

2.1.4.1Film-based or analogue mammography units:

The screen-film image receptor uses film that should be developed in a film processor often located in a dark room. The film is then visualized on a dedicated mammography view box. These units require consumable supplies such as films, chemicals, waste disposal arrangements, etc.

2.1.4.2 Digital mammography units:

The screen-film and the film processor are either replaced by a phosphor-based plate and a plate reader or by a detector and an electronic system, generating a digital image that is sent to a workstation; therefore, the film processor and dark room are no longer needed.

The image is displayed on a dedicated mammography monitor with appropriate spatial resolution and software to properly visualize it. There are also options for printing, archiving, or transmitting the image.

According to the image receptor, digital mammography is subdivided into CR technology and DR technology:

2.1.4.2.1CR technology (Computed Radiography):

Uses cassette with a phosphor-based plate in which is “read” by a special CR reader and visualized into an acquiring computer/monitor. Any existing analogue unit can be converted to CR.

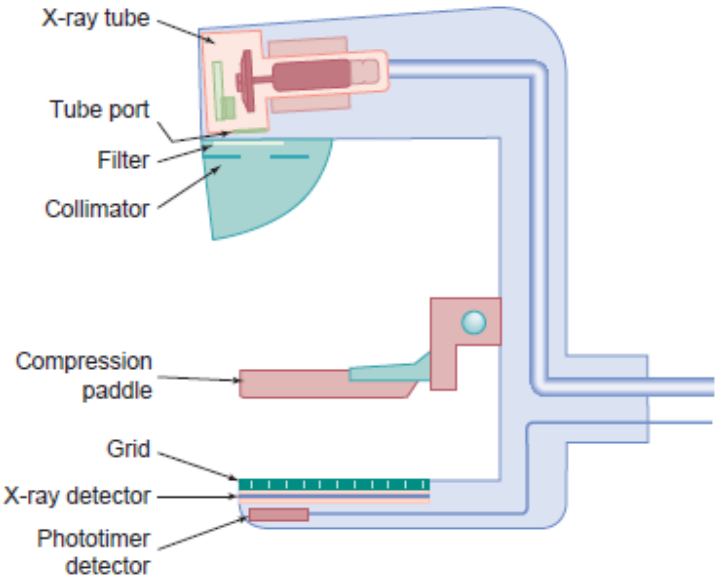
2.1.4.2.2 DR technology (Digital Radiography): the unit has a detector that directly generates the X-ray image and displays it on to the computer/monitor

(cassette-less). This kind of technology is under continuous technological advancement, such as breast tomosynthesis. The advantages include the increased acquisition speed, allowing more exams as well as enhanced image quality for some clinical situations.

Additionally, digital systems can usually be upgraded to incorporate new technologies. However, the initial capital cost is higher.

When using digital equipment, special care should be taken with the printing and archiving as it can compromise the diagnostic quality of the images. Therefore, keeping image resolution during archiving and printing is required. As a result, for the printing of clinical images, dedicated printers and image carriers designed for mammography are required. Although digital and analogue equipment have some common quality control requisites, there are also specific requirements for each of these technologies (PAHO, 2016).

2.1.5 Mammography unit:



Fiuger2.4shows the mammography system (Jerrold, 2011).

2.1.5.1 X-Ray Unit:

The mammography unit consists of an x-ray tube and an image receptor mounted on opposite sides of a mechanical assembly or gantry. Because the breast must be imaged from different aspects and to accommodate patients of different height, the height of the assembly can be adjusted, and it can be rotated about a horizontal axis.

Most general radiography equipment is designed such that the image field is centered below the x-ray source. In mammography, the system's geometry is arranged as in Figure (2.5a), in which a vertical line from the X-ray source grazes the chest wall of the patient and intersects orthogonally with the edge of the image receptor closest to the patient. If the x-ray beam were centered over the breast as shown in Figure (2.5b), some of the tissue near the chest wall would be projected inside of the patient where it could not be recorded(Inokuti, 2009).

Because of the relatively low energy of electrons used in mammography, the efficiency of x-ray production is very low, and most of the kinetic energy of

impinging electrons is dissipated in the anode as heat. To accommodate this heat while allowing the effective focal spot size used in image formation to be small, the target is formed on the surface of a rotating anode disk, and the anode is tilted with respect to the incident electrons (see Figure 2.6) so that the heat is spread over a greater area. Depending on their angle of emission, x rays formed in the target material must, therefore, traverse different path lengths through the target in traveling from their point of production to the image plane. Referring to Figure 2.6, it is seen that this causes there to be greater attenuation of x rays traveling toward the nipple side of the mammogram than toward the chest wall side. The resultant variation in x-ray fluence along the nipple chest wall axis is referred to as the heel effect.

Radiation leaving the x-ray tube passes through a tube port, generally composed of beryllium, a metallic spectrum-shaping filter, a beam-defining aperture, and a plastic plate, that compresses the breast (Inokuti, 2009).

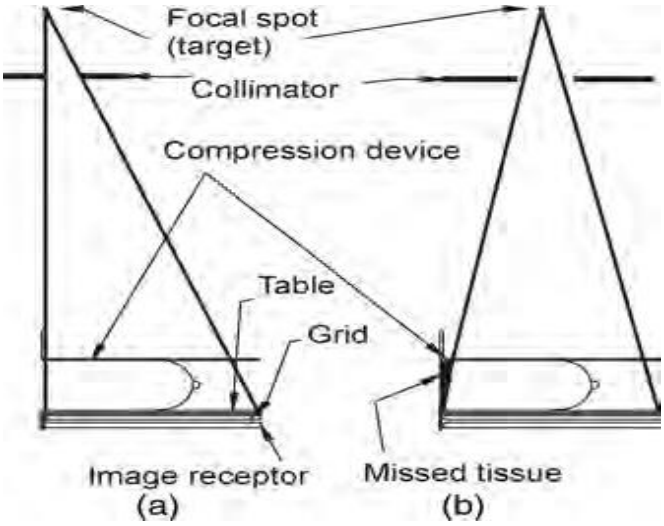


Figure (2.5), Basic beam geometry for mammography. (a) Correct alignment. (b) Incorrect alignment (Inokuti, 2009).

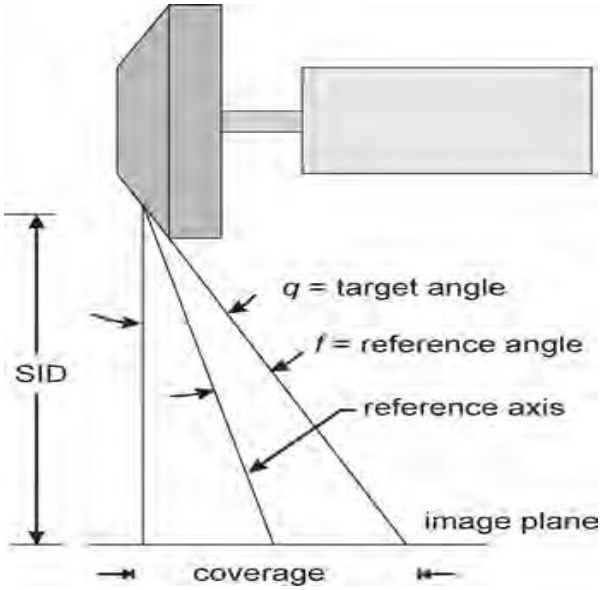


Figure (2.6) Schematic diagram illustrated a rotating-anode x-ray tube (Inokuti, 2009).

2.1.5.2Cathode and Filament Circuit:

The mammography x-ray tube is configured with dual filaments in the focusing cup to produce 0.3- and 0.1-mm focal spot sizes, with the latter used for magnification studies to reduce geometric blurring,. An important distinction between mammography and conventional x-ray tube operation is the low operating voltage, below 40 kV, which requires feedback circuits in the x-ray generator to adjust the filament current as a function of kV to deliver the desired tube current because of the nonlinear relationship between filament current and tube current. In addition, the filament current is restricted to limit the tube current, typically to 100 mA for the large (0.3 mm) focal spot and 25 mA for the small (0.1 mm) focal spot so as to not overheat the Mo or Rh targets due to the small interaction areas. Higher filament currents and thus tube currents, up to and beyond 200 mA for the large focal spot and 50 mA for the small focal spot, are possible with tungsten anodes chiefly due to a higher melting point compared to Mo and Rh anodes (Jerrold, 2011).

2.1.5.3Anode

Molybdenum is the most common anode target material used in mammography-ray tubes, but Rh and increasingly tungsten (W) are also used as targets. Characteristic x-ray production is the major reason for choosing Mo (K-shell x-ray energies of 17.5 and 19.6 keV) and Rh (20.2 and 22.7 keV) targets, as the numbers of x-rays in the optimal energy range for breast imaging are significantly increased by characteristic x-ray emission. With digital detectors, W is becoming the target of choice. Increased x-ray production efficiency, due to its higher atomic number, and improved heat loading, due to its higher melting point, are major factors in favor of W. Digital detectors have extended exposure latitude, and because post acquisition image processing can enhance contrast, characteristic radiation from Mo or Rh is not as important in digital mammography as it is with screen-film detectors (Jerrold, 2011).

2.1.6 Component of the mammography equipment:

The X- ray unit must be specifically designed for mammography and include the following key features:

1. X- ray tube with a nominal focal spot of 0.3 mm.
2. If magnification mammography is performed (this capability should be present on systems that are used for diagnostic mammography and not exclusively for screening), a magnification stand and a second, smaller focal spot of nominal size 0≤15 mm. 3. Molybdenum target. Supplementary targets composed of materials such as tungsten or rhodium may also be available.
4. Tube current ≥80 mA for a Mo target for contact mammography and ≥20 mA for magnification mammography.
5. Beryllium exit window.
6. Beam filter of molybdenum. An additional filter composed of rhodium is highly desirable.
7. Motorized compression device.
8. Readout of compression thickness and force is highly desirable;

9. Automatic exposure control (AEC) with a sensor whose position is adjustable.

10. Moving grid designed for mammography.

11. Focus–film distance ≥60 cm.

12. Buckys that can accommodate film of sizes 18 cm × 24 cm and 24 cm × 30 cm are desirable.

The room in which the mammography unit is sited should have a stable temperature and humidity for satisfactory operation. This may require appropriate air conditioning (IAEA, 2009).

2.1.6.1 Tube Port, Tube Filtration:

The tube port and added tube filters play an important role in shaping the mammography x-ray energy spectrum. The tube port window is made of beryllium. The low atomic number (Z=4) of beryllium and the small thickness of the window (0.5 to 1 mm) allow the transmission of all but the lowest energy (less than 5 keV) bremsstrahlung x-rays. In addition, Mo and Rh targets produce beneficial K-characteristic x-ray peaks at 17.5 and 19.6 keV (Mo) and 20.2 and 22.7 keV (Rh) whereas tungsten targets produce a large fraction of unwanted L-characteristic x-rays at 8 to 10 keV. Figure 2.7 shows a bremsstrahlung, characteristic and composite x-ray spectrum from an x-ray tube with a Mo target and Be window operated at 30 kV(Jerrold et al, 2011).

Added x-ray tube filtration improves the energy distribution of the mammography output spectrum by selectively removing the lowest and highest energy x-rays from the x-ray beam, while largely transmitting desired x-ray energies. This is accomplished by using elements with *K*-absorption edge energies between 20 and 27 keV.

Elements that have these K-shell binding energies include Mo, Rh, and Ag, and each can be shaped into thin, uniform sheets to be used as added x-ray tube filters. At the lowest x-ray energies, the attenuation of added filtration is very high. The attenuation decreases as the x-ray energy increases up to the K-edge

of the filter element. For x-ray energies just above this level, photoelectric absorption interactions dramatically increase attenuation as a step or "edge" function (Fig 2.8A). At higher x-ray energies, the attenuation decreases. The result is the selective transmission of x-rays in a narrow band of energies from about 15 keV up to the K-absorption edge of the filter.

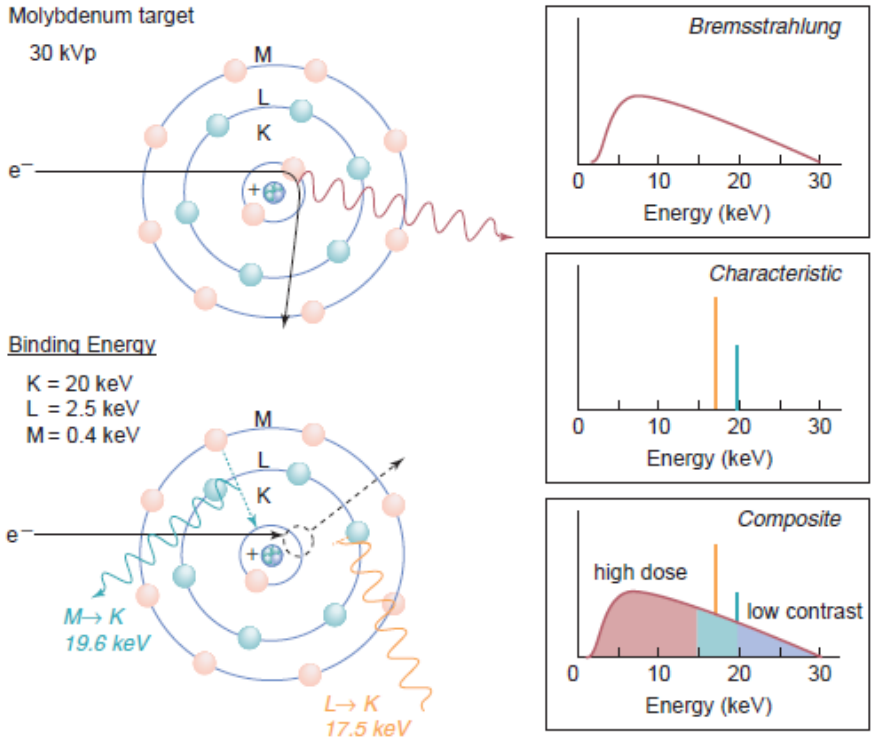


Figure (2.7) illustrates X-ray spectrum of a mammography.

X-ray tube is composed of bremsstrahlung (with a continuous photon energy spectrum) and characteristic (discrete energies) radiation Amanda tube operated at 30 kV creates the continuous spectrum as well as characteristic radiation. In Figure 2.8B, the unfiltered Mo target spectrum and a superimposed attenuation curve for a Mo filter are shown. Importantly, the characteristic x-ray energies produced by the Mo target occur at the lowest attenuation of the filter in this energy range.

With a Mo target, a 0.030-mm-thick Mo filter or a 0.025-mm Rh filter is typically used, and for Rh target, a 0.025-mm Rh filter is used. A variety of

filters are used with W targets, including Rh (0.05 mm), Ag (0.05 mm), and Al (0.7 mm) (Jerrold et al, 2011).

The spectral output of a Mo target and 0.030-mm-thick Mo filter is shown in Figure 2.9A, illustrating the selective transmission of Mo characteristic radiation and significant attenuation of the lowest and highest x-rays in the transmitted spectrum.

Tuning the spectrum to achieve optimal effective x-ray energy for breast imaging is accomplished by selecting the anode material, added filtration material, and kV.

Screen-film detectors most often use a Mo target and 0.03-mm Mo filtration with a kV of 24 to 25 kV for thin, fatty breasts and up to 30 kV for thick, glandular breasts.

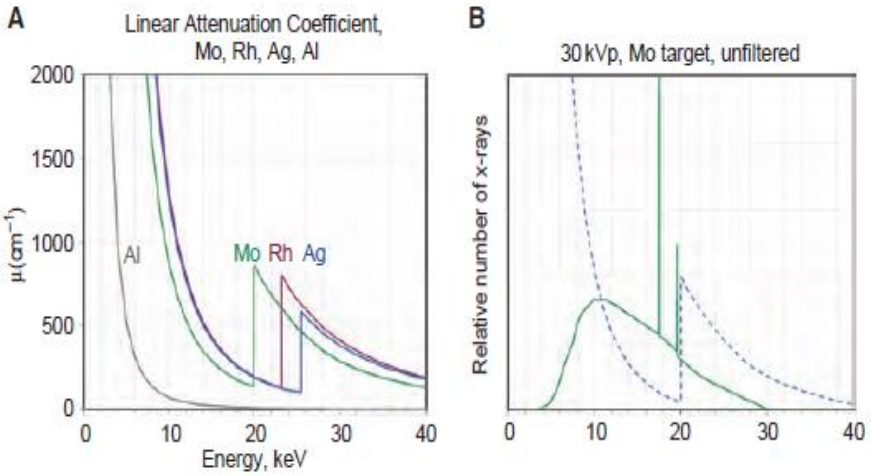


Figure (2.8) **(A)** shows linear attenuation coefficients of Al, Mo, Rh, and plotted as a function of energy. **(B)**Shows an unfiltered Mo target spectrum(Jerrold et al, 2011).

W targets are now used for many digital mammography systems because of their higher bremsstrahlung production efficiency and higher tube loadings than Mo and Rh targets. K-edge filters can optimize the output energy spectrum for breast imaging.

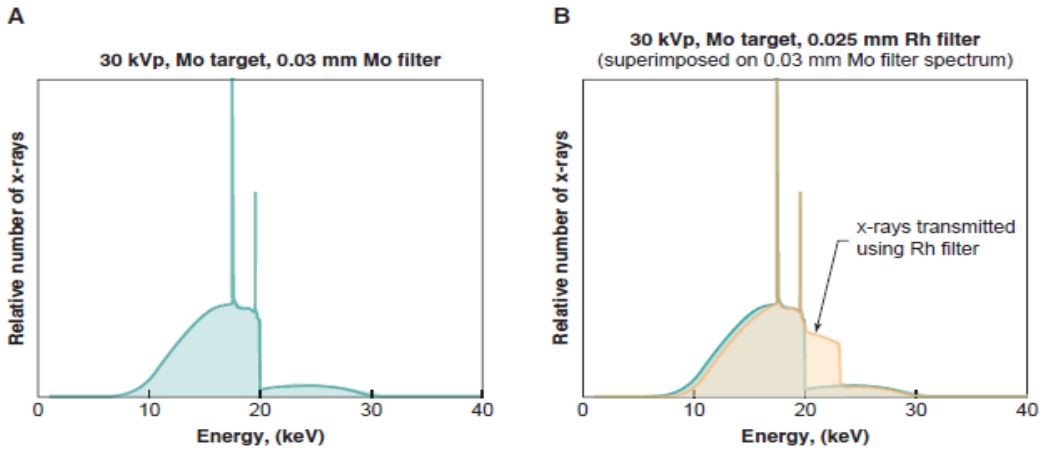


Figure2.9. (A) filtered output spectrum is shown for a Mo target and 0.030-mm Mo). **B**. A filtered output spectrum is shown for a Mo target and 0.025-mm Rh filters (Jerrold et al, 2011).

2.1.6.2 Half-Value Layer

The half-value layer (HVL) of a mammography x-ray beam ranges from 0.3 to 0.7-mmAl for the kV range and combinations of target material, filter material, and filter thickness used in mammography. The HVL depends on the target material (Mo, Rh, W), kV, filter material, and filter thickness. Measurement of the HVL is usually performed with the compression paddle in the beam, using 99.9% pure Al sheets of 0.1-mm thickness.

HVLs vary from machine to machine because of slight variation in actual filter thicknesses and kV. The HVL of breast tissue is highly dependent on tissue composition (glandular, fibrous, or fatty) and the HVL of the incident x-ray beam. Usually, the HVL for breast tissues is from 1 to 3 cm.

An x-ray beam that is “harder” than optimal indicates too much filtration or a pitted anode or aged tube and can result in reduced output and poor image quality (Jerrold et al, 2011).

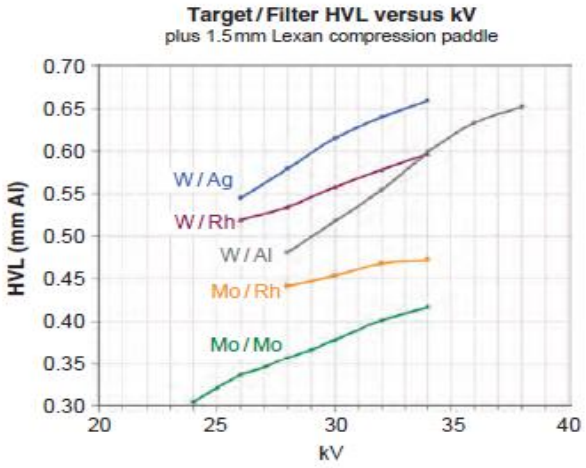


Figure (2.12) The HVL (including the compression paddle attenuation) versus kV (Jerrold et al, 2011).

2.1.6.3 Tube Output and Tube Output Rate

Tube output is a measure of the intensity of the x-ray beam, typically normalized to mAs or to 100 mAs, at a specified distance from the source (focal spot). Common units of tube output are mGy (air kerma)/100mAs and mR (exposure)/mAs. The kV, target, filter material and thickness, distance from the source, and focal spot size must be specified. Figure 8-13 shows the output at a 50-cm distance from Mo and Target x-ray tubes with a variety of tube filter materials and thicknesses. Even though

W targets are more efficient at producing x-rays, the thicker filters needed to attenuate the L-characteristic x-rays result in lower tube output per mAs compared to the Mo target. However, W spectra have higher HVLs and greater beam penetrability, allow higher tube current, and result in comparable exposure times to a Mo target and filter for a similar breast thickness. X-ray tube output values are useful for calculating the free-in-air incident air kerma (or exposure) to the breast for a mammography system's target and filter combination, kV, mAs, and source-to-breast surface distance. The source-to-breast surface distance is determined from the known SID, breast platform to

detector distance, and compressed breast thickness. For instance, assume that a mammography system with a Mo target and Rh filter uses 30 kV and 160 mAs for a SID of 65 cm, compressed breast thickness of 6 cm, and a breast platform to detector distance of2 cm. The entrant breast surface to the source is closer by 8 cm, and is therefore57 cm from the source. From Figure 2-13, the tube output is 16 mGy/100 mAs for

30 kV at a distance of 50 cm. Calculation of incident air kerma considers tube output at a specific kV, the mAs used, and inverse square law correction from 50 to 57 cm:

16 mGy/100 mAs×160 mAs×[50.0/57.0]2 =19.7 mGy

Calculation of the average glandular dose to the breast is determined from the measured incident air kerma value and other parameters.

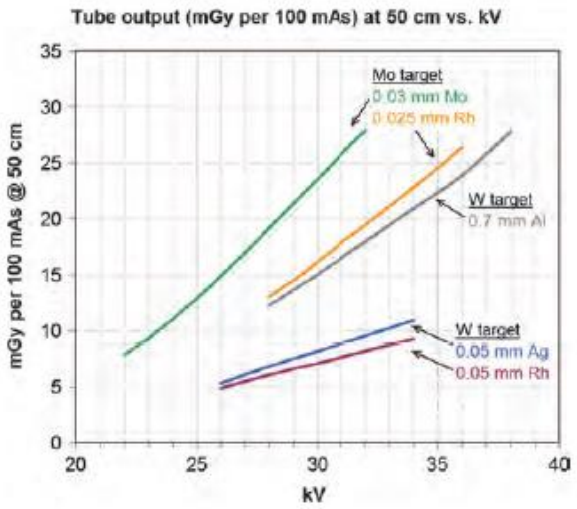


Figure 2.13 Tube output (mGy/100 m A sat 50-cm distance from the source with compression paddle in the beam) (Jerrold et al, 2011).

Tube output rate is the air kerma rate at a specified distance from the x-ray focal spot and is a function of the tube current achievable for an extended exposure time (typically ~300 mAs for an exposure time greater than 3 s). To ensure the ability to deliver a sufficient x-ray beam fluence rate to keep exposure times reasonable, MQSA regulations require that systems be capable of producing an air kerma rate of at least 7.0 mGy/s, when operating at 28 kV in the standard

(Mo/Mo) mammography mode, at any SID for which the system is designed to operate for screen-film detectors. Digital systems have requirements specified by the manufacturers' QC manuals (Jerrold et al, 2011).

2.1.7Quality assurance in mammography:

A QA programme in diagnostic radiology, as defined by WHO, is an organized effort by the staff operating a facility to ensure that the diagnostic images produced are of sufficiently high quality so that they consistently provide adequate

diagnostic information at the lowest possible cost and with the least possible exposure of the patient to radiation. Registrants and licensees shall establish a comprehensive QA programme for medical diagnosis with the participation of appropriate medical physicists, taking into account the principles established by WHO(IAEA, 2009).

For successful x-ray mammography screening, mammograms must contain the best possible diagnostic information obtainable. The image quality must be stable with respect to information content. The radiation dose to the breast must be as low as reasonably achievable for the diagnostic information required. These demands on image quality hold for every mammogram produced and the Quality Assurance programme must ensure that high quality images are achieved consistently.

Quality assurance of physical and technical aspects of mammography must include equipment specification, acceptance testing and routine quality control.

The Quality Assurance programme must be able to guarantee optimal performance and status of the entire imaging chain:

•Image acquisition, which includes the x-ray generation, the image receptor and image receptor corrections

• Image processing, this includes the image processing software.

• Image presentation including diagnostic monitors, image presentation software, printers and viewers.

Following the installation of any new x-ray or ancillary imaging equipment, a detailed series of acceptance and commissioning tests must be performed in order to ensure that the equipment meets specification and to establish the baseline performance of the equipment.

Routine quality tests must then be performed at regular intervals and after maintenance or repairs to detect whether any change in the performance of the equipment has occurred.

In addition to the routine quality tests carried out on all machines, each system will be subject to specific tests recommended by the manufacturers.

Technical and physics QA provides the only objective assessments of two important parameters: image quality and radiation dose, and is most appropriately carried out by medical physicists and radiographers in close co-operation and in consultation and communication with Breast Check radiologists (National Cancer Screening Service Board, 2008)..

2.1.7.1Electrical safety:

The physicist should ensure at installation that appropriate electrical safety checks are performed by the installing engineer.

At acceptance, the physicist should ensure that a visual inspection of all electrical cables and connectors is performed.

2.1.7.2Mechanical safety and function:

At acceptance, the physicist should check that the equipment is complete by reference to the specification.

All manual and automatic mechanical functions should be systematically checked.

2.1.7.3Radiation safety:

Mammography units differ from general x-ray units in the use of lower energy radiation and a specialised geometry. The x-ray field is permanently aligned with the patient support table, which also acts as a primary beam absorber (National Cancer Screening Service Board, 2008).

2.1.7.4 X-ray room protection:

Lead-equivalence of protective screens should be marked and be checked.

Environmental radiation under normal working conditions may be checked if necessary using monitoring badges positioned around the room.

2.1.7.5Visual Inspection:

An inspection of the equipment and room for radiation protection aspects should be made. This inspection should include the following checks:

• Primary collimation should be fitted.

• Verify that exposure switch is behind lead screen.

• Verify that exposure terminates if button is released prematurely.

• Verify that design of exposure switch prevents inadvertent production of X-rays.

• Verify that all controls are clearly marked.

• Verify that all indicator lights are functioning correctly.

• Verify focal spot position and tube filtration marked.

• Verify operation of emergency stop.

• Verify radiation signs are satisfactory.

• Verify room in use lights are working.

• Verify Pb equivalence of protective screens is marked.

• Verify condition of protective screens is satisfactory.

2.1.7.6 Table assembly transmission:

The table assembly is normally regarded as a primary beam absorber, so the x-ray beam should normally lie within and not significantly overlap its edges.

A simple check uses a solid state detector placed beneath the breast table and it is exposed using a low exposure (10mAs).

No primary beam or scattered radiation should be detected within and around the table assembly.

2.1.7.7 Leakage radiation:

Defects in tube shielding are unusual but in view of the proximity of the tube housing to the woman being examined, it is important that leakage radiation be checked. This measurement requires first the location of any leakage followed by the measurement of its intensity (National Cancer Screening Service Board, 2008).

2.1.8 Quality Control:

Quality control for mammography machines has been assessed including output reproducibility mGy, kVpaccuracy & reproducibility, AEC performance linearity, Mean Glandular Dose mGy, HVL (mm/Al), Breast thickness indicator as well as compression test(British Journal of Medicine & Medical Research,2016)

2.1.8.1 Kilovoltage and mA:

The accuracy of tube potential is important. Two values should be assessed: the "average peak kV" during the exposure and the range of peak voltages over the exposure time. The peak kV should be approximately constant during the entire duration of the exposure without spikes or sagging. The peak tube potential should, therefore. Be sampled at 0.05 s, 0.50 s, 1.0 s, and 2.0 s to ensure that its average is within ±0.5 kV from the set kVp-value.

The tube current during the exposure should be sampled in the same manner as the tube potential with an allowable accuracy of ±10%.

2.1.8.2 Beam Quality:

Beam quality is dependent on kVp, voltage waveform and beam Filtration. Variations in any of these may be detected by comparing the HVL of the x-ray beam under fixed operating conditions to previous measurements or to measurements taken on identical equipment.

2.1.8.3. Tube Output - mR/mAs (free in air):

This measurement provides fundamental information on the performance of the x-ray generator, tube and filtration; allows one to determine whether the unit can produce images with acceptably short exposure times, and enables calculation of breast exposure and dose (Marlin J. Yaffe, 1990).

2.1.8.4. Collimation and alignment:

Proper collimation of the x-ray field is necessary to ensure there are no unexposed portions of the image receptor and that patients are not needlessly exposed to stray radiation.

Proper alignment of the edge of the compression paddle with the chest-wall edge of the image-receptor holder assembly is necessary for proper positioning and compression of the breast (American association of physicists in medicine, 2006).

2.1.9 QC Tests - Annual:

Annual quality control tests Facilities with screen-film systems shall perform the following quality control tests at least annually:

(A) Automatic exposure control performance:

1-The AEC shall be capable of maintaining film optical density within <plus-minus> 0.30 of the mean optical density when thickness of a homogeneous material is varied over a range of 2 to 6 cm and the kVp is varied appropriately for such thicknesses over the kVp range used clinically in the facility. If this requirement cannot be met, a technique chart shall be developed showing appropriate techniques (kVp and density control settings) for different breast thicknesses and compositions that must be used so that optical densities within <plus-minus> 0.30 of the average under phototimed conditions can be produced.

2-After October 28, 2002, the AEC shall be capable of maintaining film optical density (OD) within <plus-minus> 0.15 of the mean optical density when thickness of a homogeneous material is varied over a range of 2 to 6 cm and the

kVp is varied appropriately for such thicknesses over the kVp range used clinically in the facility.

3-The optical density of the film in the center of the phantom image shall not be less than 1.20.

(B)Kilovoltage peak (kVp) accuracy and reproducibility:

The kVp shall be accurate within <plus-minus> 5 percent of the indicated or selected kVp at:

.The lowest clinical kVp that can be measured by a kVp test device;

.The most commonly used clinical kVp;

.The highest available clinical kVp, and At the most commonly used clinical settings of kVp, the coefficient of variation of reproducibility of the kVp shall be equal to or less than 0.02.

C- Focal spot condition:

Until October 28, 2002, focal spot condition shall be evaluated either by determining system resolution or by measuring focal spot dimensions. After October 28, 2002, facilities shall evaluate focal spot condition only by determining the system resolution.

1-System Resolution.

.Each X-ray system used for mammography, in combination with the mammography screen-film combination used in the facility, shall provide A minimum resolution of 11 Cycles/millimeters (mm) (line-pairs/mm) when a high contrast resolution bar test pattern is oriented with the bars perpendicular to the anode-cathode axis, and a minimum resolution of 13 line-pairs/mm when the bars are parallel to that axis.

2-Focal spot dimensions. Measured values of the focal spot length (dimension parallel to the anode cathode axis) and width (dimension perpendicular to the anode cathode axis) shall be within the tolerance limits (FDA, 2000).

D- Breast entrance air kerma and AEC reproducibility.

The coefficient of variation for both air kerma and mA's shall not exceed 0.05.

E-Dosimetry.

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

F- X-ray field/light field/image receptor/compression paddle alignment:

1-All systems shall have beam-limiting devices that allow the entire chest wall edge of the x-ray field to extend to the chest wall edge of the image receptor and provide means to assure that the x-ray field does not extend beyond any edge of the image receptor by more than 2 percent of the SID.

2-If a light field that passes through the X-ray beam limitation device is provided, it shall be aligned with the X-ray field so that the total of any misalignment of the edges of the light field and the X-ray field along either the length or the width of the visually defined field at the plane of the breast support surface shall not exceed 2 percent of the SID.

3-The chest wall edge of the compression paddle shall not extend beyond the chest wall edge of the image receptor by more than one percent of the SID when tested with the compression paddle placed above the breast support surface at a distance equivalent to standard breast thickness. The shadow of the vertical edge of the compression paddle shall not be visible on the image (FDA, 2000).

G- Uniformity of screen speed:

Uniformity of screen speed of all the cassettes in the facility shall be tested and the difference between the maximum and minimum optical Densities shall not exceed 0.30. Screen artifacts shall also be evaluated during this test.

H- System artifacts.

System artifacts shall be evaluated with a high-grade, defect-free sheet of Homogeneous material large enough to cover the mammography cassette and shall be performed for all cassette sizes used in the facility using a grid appropriate for the cassette size being tested. System artifacts shall also be evaluated for all available focal spot sizes and target filter combinations used clinically.

I- Radiation output:

1- The system shall be capable of producing a minimum output of 4.5 mGy air kerma per second (513 milli Roentgen (mR) per second) when operating at 28 kVp in the standard mammography (moly/moly) mode at any SID where the system is designed to operate and when measured by a detector with its center located 4.5 cm above the breast support surface with the compression paddle in place between the source and the detector. After October 28, 2002, the system, under the same measuring conditions shall be capable of producing a minimum output of 7.0 mGy air kerma per second (800 mR per second) when operating at 28 kVp in the standard (moly/moly) mammography mode at any SID where the system is designed to operate.

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

J-Decompression:

If the system is equipped with a provision for automatic decompression after completion of an exposure or interruption of power to the system, the system shall be tested to confirm that it provides:

1-An override capability to allow maintenance of compression;

2- A continuous display of the override status;

3-A manual emergency compression release that can be activated in the event of power or automatic release failure(FDA,2000).

2.1.10. Image Quality:

The information content of an image may best be defined in terms of just visible contrasts and details, characterized by its contrast-detail curve. The basic conditions for good performance and the constancy of a system can beassessed by measurement of the following: resolution, contrast visibility, threshold contrast and exposure time.

2.1.10.1 Spatial resolution

One of the parameters which determine image quality is the system spatial resolution. It can be adequately measured by imaging two resolution lead bar patterns, up to 20 line pairs per mm (lp/mm) each.

2.1.10.2 Image contrast

Since image contrast is affected by various parameters (like tube voltage, film contrast etc.) this measurement is an effective method to detect a

2.1.10.3 Threshold contrast visibility

Extensive test: Threshold contrast visibility is determined for circular details with diameters in the range from 0.1 to 2 mm. The details are imaged on a background object with a thickness equivalent (in terms of attenuation) to 50 mm of PMMA.

2.1.10.4 Exposure time:

Long exposure times can give rise to motion unsharpness. Exposure time may be measured by some designs of kVp- and output meters. Otherwise a dedicated exposure timer has to be used. (Van Engen, 2005).

2.1.11Mammography Phantoms:

Mammographic phantoms with a variety of features are available commercially. The phantom used in the ACR Mammography Accreditation Program is a clear acrylic phantom25 that is equivalent to a 4.2 cm compressed breast (50% adipose, 50% glandular) (Robert, 1990)

2.2Previous Studies

The researcher did not manage to find any previous studies which are specifically relevant to QC in mammography machines. The researcher looked into the available textbooks at the library of the College of Medical Radiologic Science, and into many internet sites for this purpose.

Chapter Three

Materials and Methods

Chapter Three

Materials and Methods

3.1 Materials:

3.1.1 X-ray Unit:

Two X-ray machines with CR (Computed Radiography) system image plate + Reader + display unit + printer, in two centers (center A without AEC and center B with AEC). Table 3.1 presented the specification of x-ray tube, compressor, and x-ray generator.

Table 3.1 specifications of x-ray unit in center A&B

Specification	Center A	Center B
x-ray generators	SIEMENS	LILYUM
Serial N.O	55643	-
X-ray tube	Mammomat C	MetalRonica
Serial N.O	01244	601066
Compressor serial N.O	01259	-

Figure 3.1 Mammography unit and console

3.1.2 Quality Control Tools:

3.1.2.1 Patient dose tools

-Semiconductor detector (Piranha+display unit (palm))

- AL sheets (0.1 mm thickness)

- PMMA thickness (0.5mm thickness)

The Specification of dosimetry equipment is presented in table 3.2 for dosimeter and display unit and figure 3.2 illustrate the dosimeter and display unit.

Table 3.2 Specifications of Dosimetry QC equipment

Semiconductor detector (Piranha)	RTI electronics, S/N CB2-08120153
display unit (palm)	Palm , TUNGSTEN,PN20MAT70R29R

Figure 3.2Semiconductor detector (Piranha) and display unit (palm)

3.1.3 Image Quality Tools

3.1.3.1 TOR MAX

Is the Phantom used for evaluation the image quality, semi-circle shape contained different structures illustrated in table 3.3

Table 3.3 TOR MAX Description

Sensitometry	Ten-step grey-scale plus two points for Sensitometric measurements)
High Resolution limit	(1.0 to 20.0 LP/mm) x2 for TOR MAX
Low Contrast Resolution	1.8 to 5 line pairs/mm, representing filamentary structures
Low-contrast large-detail detectability	(12 details, 5.6mm diameter)
High-contrast small-detail detectability	11 details, 0.5 and 0.25mm diameter

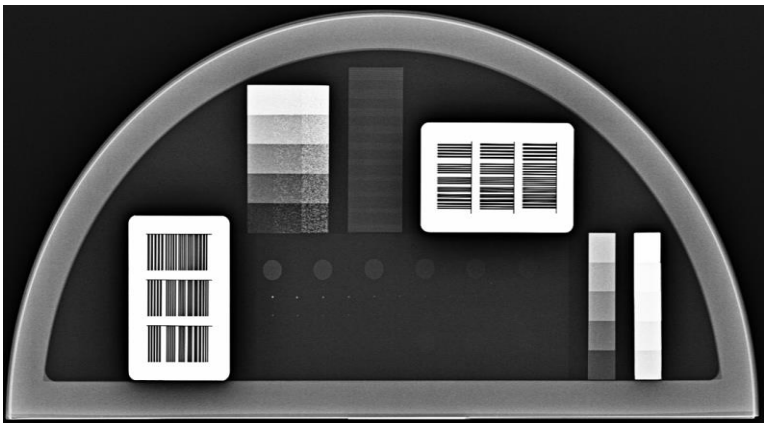


Fig.3.3 TORMAX

3.1.3.2 TOR MAM:

Is the semi-circle shape with 240mm diameter, table 3.4 illustrated the structures of the phantom.

Table 3.4 structures of TOR MAM

Filaments	6 groups of multi-directional filaments
Micro-calcifications	6 groups of micro-calcifications in ranges of 354-224, 283-180, 226-150,177-106, 141-90, 106-93
Threshold Contrast Details	6 groups of 3, low contrast details groups

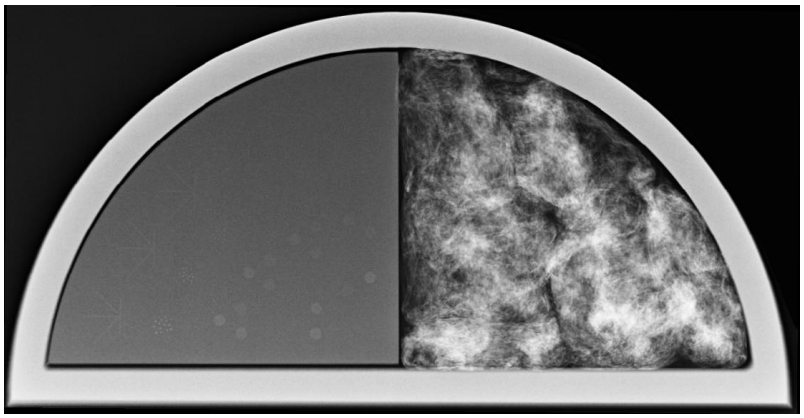


Fig.3.4 TORMAM

3.1.3.3 Densitometer**:** to measure the optical density (OD) Table 3.5 illustrated the specification of densitometer

Table 3.5 the specification of Densitometer

Densitometer	X-RITE331,S/N033174

Fig.3.5 Densitometer

3.2 Methods

The tests of QC for mammography were performed using the tools that mentioned above to evaluate the patient dose and image quality of mammography unit. Groups of tests were performed using QC tools.

3.2.1 Specific Radiation output:

The air kerma was measured in air at (Focal to Film Distance) FFD 50 cm and 26 kVp, 14 mAs were used in center A, Kvp 26.5, mAs 2.9 in Center B. The detector was placed in the breast support and at 4 cm from the chest wall, the values were recorded four times and the average was calculated.

3.2.2. Output variation with kVp:

This test was performed to evaluate the variation of output when Kvp is changed, mAs was set at fixed values 18 mAs in center A, mAs 16 in center B, exposure done and the output of each exposure was recorded, and the average was calculated.

3.2.3. Output Variation with mAs:

This test was done to evaluate the effect of mAs changing when the Kvp is fixed, the Kvp was set in 26 in center A, Kvp 25in center B the mAs changing using different values, the output was recorded and the average was calculated.

3.2.4. Half value layer (HVL):

The parameters for exposures were selected, 26 Kvp, and 16 mAs. The first exposure was done without Added any filter and the measurement was recorded. For the second exposure we added 1mm of Al and the measurement was recorded. For other measurements we added1 mm for each reading until arrived the half values of the first reading. The diagram was plotted between output reading against the added thickness of Al(mm) we got exponential curve,

The cross of the half value of the first reading (without filter) with curve will give the HVL in x –axis.

3.2.5. Mean Glandular Dose:

This test was performed to evaluate the mean Glandular dose (MGD) using PMMA phantom, clinical exposure setting was used for a 5.3 cm breast, at 28kVp, and 18 mAs Exposure of equivalent to 4.5 cm PMMA the measurements of air kerma (K_{air}) were repeated three times and the average was calculated. The value of MGD was calculated from the equation:

$$MGD=K_{air}.g.\ s.c$$

K_{air}: is the entrance air kerma at the surface of the 45 mm thickness of PMMA, measured without backscatter);

g_{53}: is the factor that converts the entrance air kerma to the mean glandular dose for the 53 mm thick standard breast;

c_{53}: is the conversion factor which allows for the glandularity of the 53 mm thick standard breast;

S: is the factor which gives a correction that depends on the target filter combination.

3.2.6Image Quality Evaluation :

3.2.6.1TOR MAM:

Test object Placed on 3mm PMMA on breast suport, the parameters was selected 28 kvp,16 mAs. From the image of the phantom we measured the optical density

by densitomitre devise and we got: background densities B1, B2 at two different points, and the visiblity of the filament, particles, circular details was done visually.

3.2.6.2 TOR MAX

Test object (TOR MAX) Placed on 3.5 mm thickness of PMMAon breast suport, from the image of tese object and the paramters were seted 30 Kvp and 16 mAs,from the image of TORMAX we determine the data presented in table below:

Table(3.6) is measurement of diffrent optical density

Parameters	TORMAX
Mean Back ground density	Measurement of area of the low contrast details
High density point	Optical density of circle with high density
Base+fog	step 1 in gray scale or circular test Base+fog
Scatter	step 1 in gray scale - circular test Base+fog
Speed index	step 9 or step 10 in Gray scale
Contrast Index	speed index - high density point
Visual Contrast	1- (High density/background)
Resolution limit	Two resolution pattern(right and left) grating lp/mm
Low contrast sensitivity	Counting of circular details 6mm diameter
Small details visibility	0.5 mm and 0.25 mm details

Chpter Four

Results

Chpter Four

Results

4.1 Specific Radiation output

Table 4.1.1 Center A: Kvp = 26, mAs = 14

Output (µGy)	µGy/mAs
1124	80.29
1124	80.29
1126	80.43
1122	80.14
Avg	80.29
Sdv	0.12

Table4.1.2 Center B: Kvp = 26.5, mAs = 2.9

Output (µGy)	µGy/mAs
247	85.2
247	85.2
245	84.5
Avg	84.9
Sdv	0.39

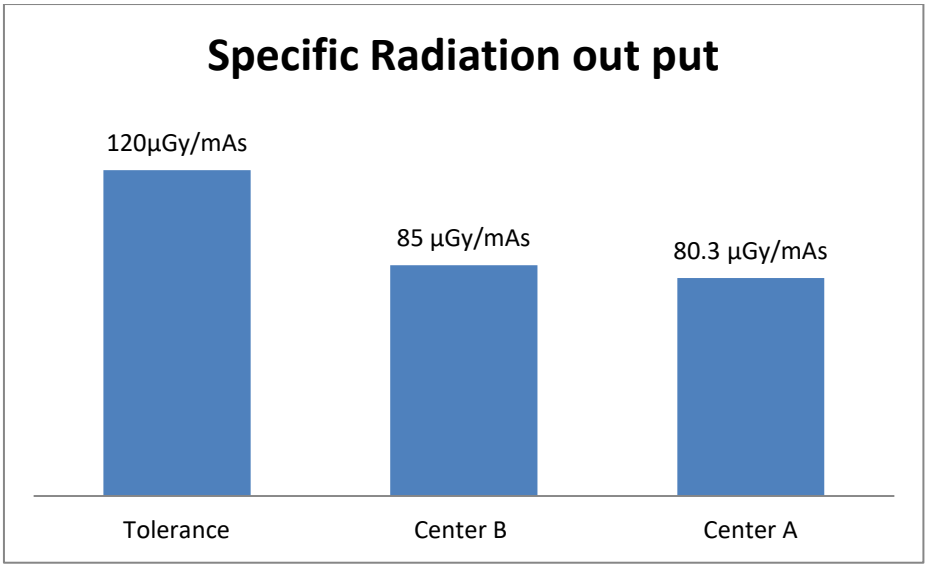


Figure 4.1 specific outputs of Center A& B and the tolerance from IPEM

4.2 Output Variation with Kvp

Table 4.2.1 Output Variation with Kvp Center A: mAs = 18

Kvp	Output(µGy)
26	1449
28	1836
31	2501
Avg	1929

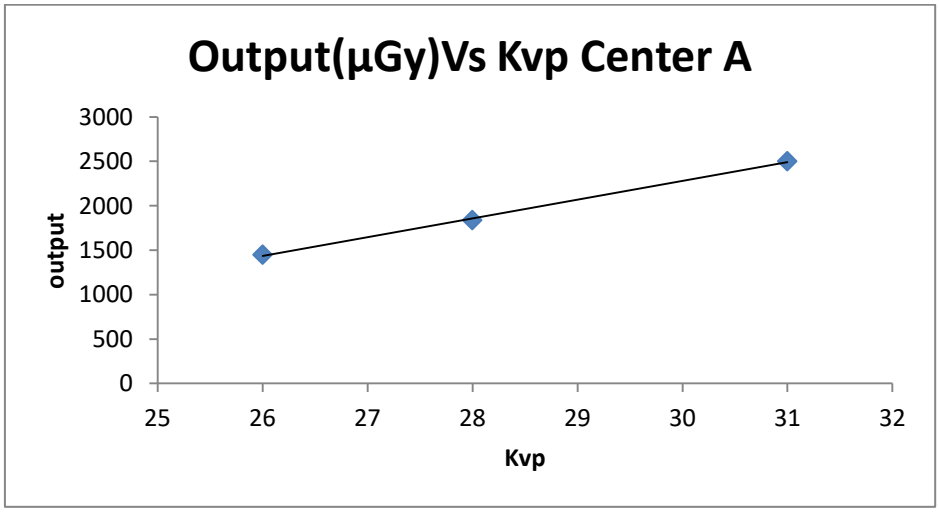


Figure 4.2Output Variation with Kvp Center A

Table4.2.2 Output Variation with Kvp Center B: mAs = 16

Kvp	Output(µGy)
24	949
25	1095
26	1241
Avg	1095

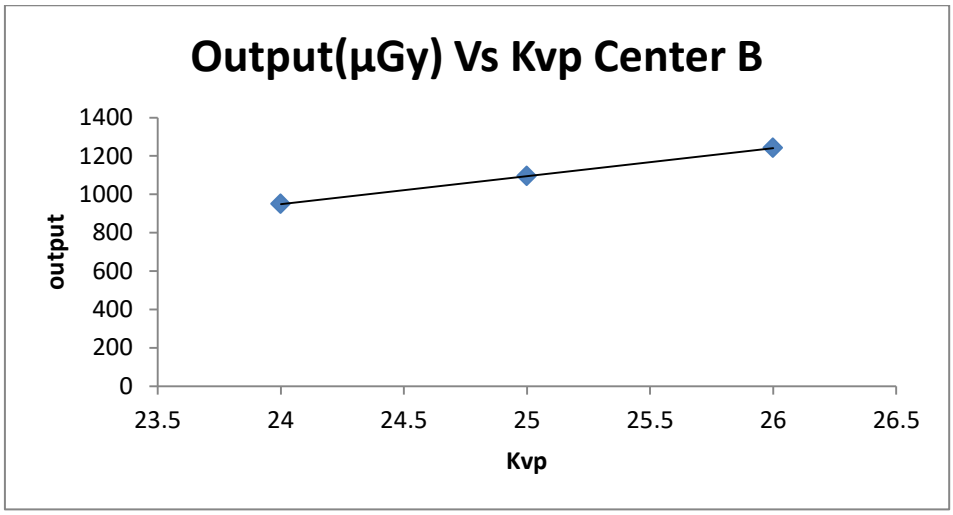


Figure 4.3Output Variations with Kvp Center B

4.3 Output Variation with Kvp

Table 4.3.1Output Variation with mAs Center A: Kvp = 26

mAs	Output(µGy)	Output/mAs	%Error
12.5	1011	80.9	0.2
14	1125	80.4	0.5
16	1295	80.9	0.3
Avg	1144	80.7	

Table 4.3.2Output Variation with mAs Center B: Kvp = 25

mAs	Output(µGy)	Output/mAs	%Error
16	1097	68.6	0.04
20	1373	68.7	0.09
25	1714	68.6	0.04
Avg	1395	68.6	

4.4 Half Value Layer

Table 4.4.1 Half Value Layer (HVL) Center A

Added Filters (mm Al)	Reading
0	1295
1	1054
2	846.5
3	718.2
4	602.3
HVL	**0.35**

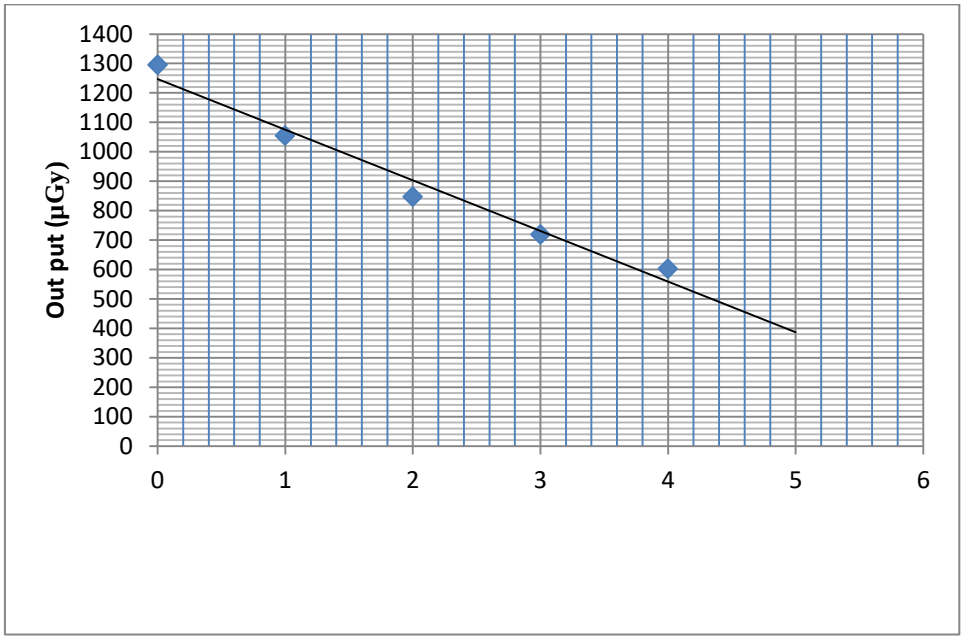


Figure 4.4Half Value Layer Center A

Table4.4.2 Half Value Layer (HVL) Center B

Added Filters (mm Al)	Reading
0	1374
1	1116
2	918
3	766
4	637
HVL	**0.38**

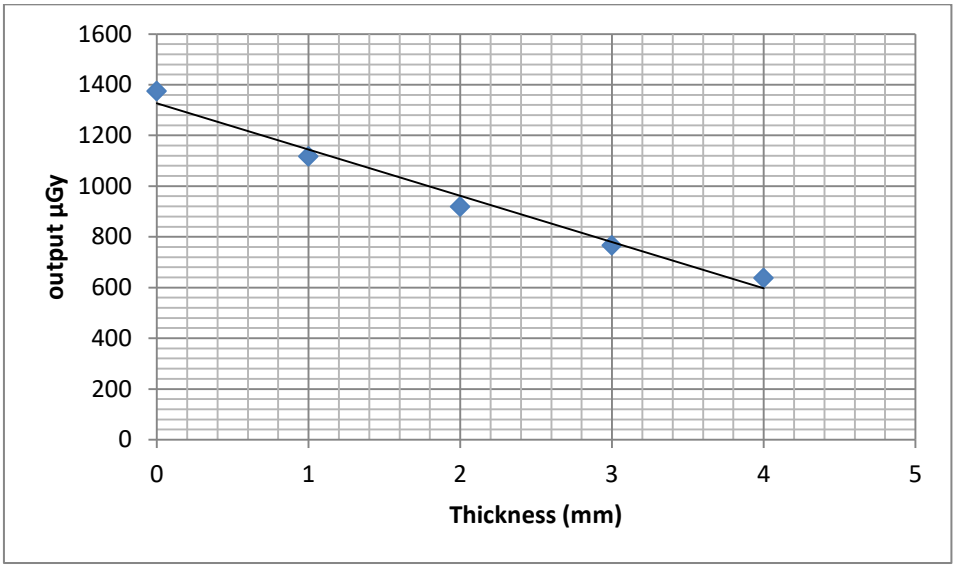


Figure 4.4Half Value Layer Center B

4.5 Mean Glandular Dose

Table4.5.1 Mean Glandular Dose Center A

Kvp = 28, mAs = 18

NO	Kair
1	1838
2	1838
3	1842
Avg	1839.3

MGD = Kair*s*g*c

MGD = 1839.3*0.177*1.105*1

MGD = 359.7 µGy = 0.36 mGy

Table4.5.2 Mean Glandular Dose Center B

Kvp = 24.5, mAs = 102.7

NO	Kair
1	247
2	247
3	245
Avg	246.3

MGD = Kair*s*g*c

MGD = 246.3*0.198*1.102*1

MGD = 53.7 µGy = 0.054mGy

4.6 Image Quality Test

4.6.1 TOR MAM

Table 4.6.1.1 TOR MAM Center A

Kvp = 28, mAs = 16, 3mmPMMA thickness

Back ground densities		Filament	Particles	Circular details
B1=1.59	B2=1.25	1	2	3

Table 4.6.1.2 TOR MAM Center **B**

Kvp = 22, mAs = 2, 3mmPMMA thickness

Back ground densities		Filament	Particles	Circular details
B1=1.15	B2=1.23	1	2	3

4.6.2 TOR MAX =3.5mm(PMMA)

Table 4.6.2.1 TOR MAX Center A, KVp=30, mAs=16, phantom thickness

Densitey measurement TOR MAX

Mean Back ground density	**1.46**	
High density point (>1.5)	**1.9**	
Base+fog	**0.22**	**0.21**
Scatter	**0.01**	
Speed index	**1.62**	
Contrast Index	**0.28**	
Visual Contrast	**0.62**	

Unshrpness measurment

RHS Grating	**11Groups**
LHS Grating	**11Groups**

Low contrast sensitivty

Details Diameter	Count of DetailsVisibilty
6 mm	5
0.5mm	6
0.25mm	2

4.6.2.2 TOR MAX, Center B, KVp=22, mAs=2, phantom thickness =3.5mm(PMMA)Densitey measurement TOR MAX

Mean Back ground density	**1.42**	
High density point (>1.5)	**1.68**	
Base+fog	**0.20**	**0.19**

Scatter	**0.01**
Speed index	**1.15**
Contrast Index	**0.53**
Visual Contrast	**0.11**

Unshrpness measurment

RHS Grating	**12Groups**
LHS Grating	**12Groups**

Low contrast sensitivty

Details Diameter	Count of DetailsVisibilty
6 mm	5
0.5mm	5
0.25mm	3

Chapter five

Discussion

Chapter five

Discussion

In this chapter we discussed the results of the work and we compared the data from two centers (A&B) with values of standards from: Mammography IAEA Human Health SeriesNO.2, and IPEM Protocol.

Regarding the specific radiation output in tables (4.1.1, 4.1.2) the values of the two centers under study were accepted as compared with the tolerance from IPEM (< 120µGy/mAs) values. Center B got higher value (85µG/mAs) than center A (80.3µG/mAs).

Concerning the output variation with kVp in tables (4.2.1, 4.2.2) in both centers there was linear relationship between output and kVp (when the kVp increased, the output increased). In this test the mAs was fixed.

For output variation with mAs in tables (4.3.1, 4.3.2) the relationship was linear and the variation in output in the two centers within the tolerance range< ±10%.

Regarding the HVL for both centers in (tables 4.4.1, 4.4.2)the values within acceptable range (HVL>0.3mm Al and <0.4mm Al).

For the MGD, the values of two centers in table (4.5.1, 4.5.2) with PMMA 4.5 cm, the thick ness was within the acceptable rangeofIAEA (≤2 mGy).

Regarding the image quality test all the values were within the tolerance of IAEA human health series No.2 and IPEM report 91, and these values can be used as baseline for future image quality evaluation.

5.2. Conclusion:

A systematic approach for assessing critical performance indicators can be achieved through the implementation of a quality assurance (QA) program. QA provides a framework for constant improvement through a feedback mechanism. It allows the identification of deviations from optimum performance of mammographic equipment. This study was done to achieve the above mentioned goal. It was carried out in two X-ray centers, namely AL-Neelain Medical Diagnostic Center, and Royal Care International Hospital, during the period from October to December 2017. The study has come out with many important results including that all the measured quality control parameters were within the normal limits according to the international standards. The study also proposed some recommendations and future studies which could be useful in this field

5.3. Recommendations:

Using of automatic exposure control in mammography (AEC) is very important for image quality and patient dose determination.

The daily and weekly quality control test is essential for each mammography unit.

Well training of X-ray technologists in QC procedures helps to improve the performance.

The medical physicists should have clear job description for quality control in all diagnostic centers.

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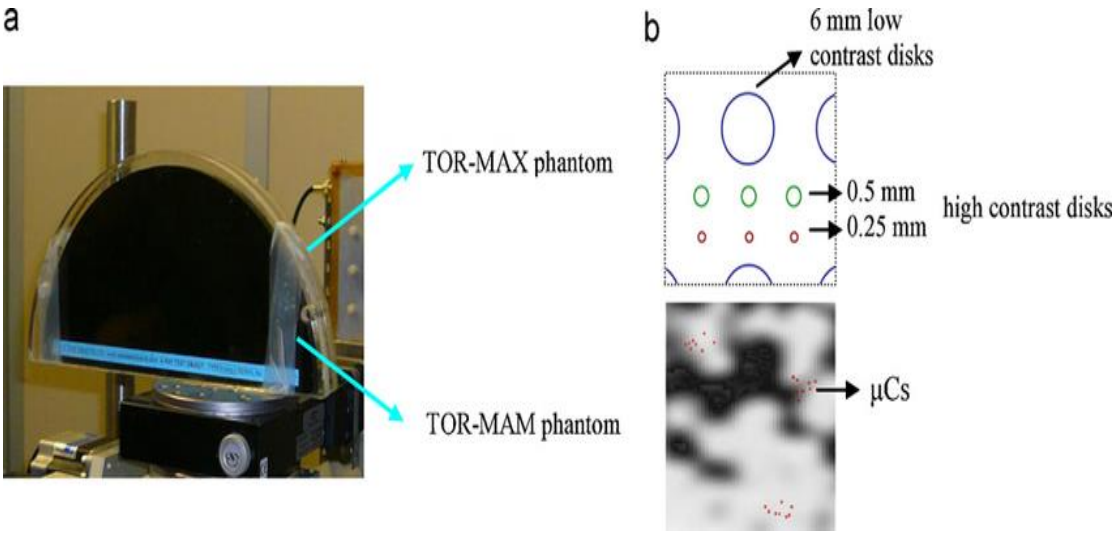
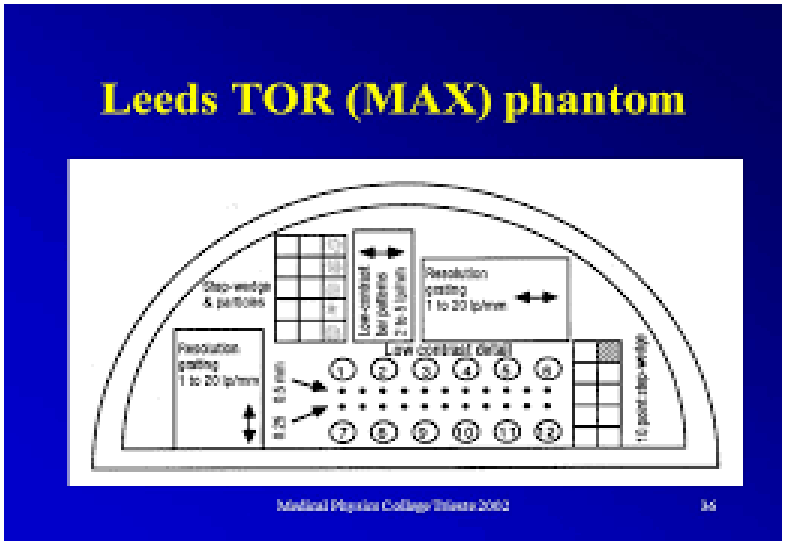
Appendices

Appendices

App. (1) Leeds test object

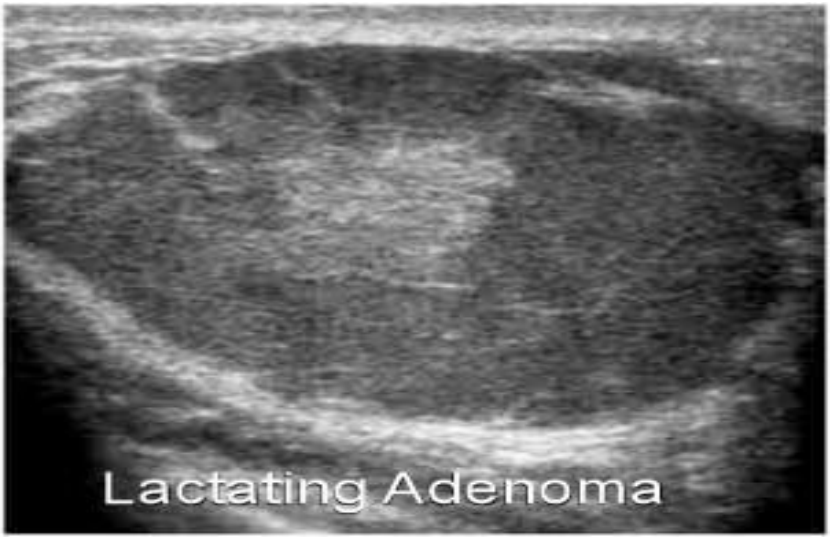


App. (2) TOR-MAM&TOR- MAX



App.(3)TOR-MAX Phantom

App. (4) TOR-MAM phantom



App. (5) Lactating Adenoma

SUDAN ATOMIC ENERGY COMMISSION
RADIATION PROTECTION AND ENVIRONMENTAL MONITORING DEPARTMENT

QUALITY CONTROL PROCEDURE FOR DIAGNOSTIC X-RAY UNITS

INSPECTION No.		DATE	
NAME OF INSTITUTE			
Address			
ROOM NUMBER		TEL.No.	

X-RAY GENERATOR			
MANUFACTURER			
MODEL		SERIAL No	
DATE PURCHASED			
DATE OF LAST MAINTENANCE		REPAIR	
FIXED		MOBILE	
TYPE			
MAXIMUM KVp			

X-RAY TUBE			
MANUFACTURER			
MODEL		SERIAL No.	
RADIOGRAPHIC		FLUORO	
DATE INSTALLED		FOCAL SPOT SIZE	
DATE OF LAST MAINTENANCE		**REPAIR**	

TARGET MATERIAL		**FILTER MATERIAL**	
TOTAL FILTERATION			
OPERATIONAL MANUAL		**SERVICE MANUAL**	.

			STAFF
	3		1
	4		2

REMARKS

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1	MECHANICAL SAFETY AND FUNCTION			
Emergency off Function	**A**		**N/A**	
Power Movement Inhibited Under Compression	**A**		**N/A**	
Emergency Compression Release Function	**A**		**N/A**	
Foot Switches Operate	**A**		**N/A**	
No Sharpe Edges	**A**		**N/A**	

2	TYPICAL RADIOGRAPHICEXPOSURE TIMES	
No.	4 cm of PMMA	7 cm of PMMA
1.		
2.		
3.		
Average		
Acceptable *		
*	**< 1 sec**	**< 4 sec**

3	SPECIFIC RADIATION OUTPUT		
FFD: 50 cm	**Kvp: 28**	**Target/Filter: Mo/Mo**	**mAs: 40**
Positioning: **Measured in air on an axis intercepting the breast support on the midline and 4 cm from the chest wall edge with the absence of the compression paddle.**			
No.	**mGy**		
1.			
2.			
3.			
Average			
Acceptable *			
*	**< 120 µGy/mAs at 50 cm, or < 70% of baseline**		

4	OUTPUT VARIATION WITH KVP		
FFD: 50 cm	**Target/Filter: Mo/Mo**		**mAs: 16**
No.	Kvp	O/P	
1.			
2.			
3.			
Average			
Acceptable *			
*			

5	OUTPUT VARIATION WITH mAs			
FFD: 50 cm	**Target/Filter: Mo/Mo**		**Kvp: 25**	
No.	mAs	Output	Output/mAs	% Error
1.				
2.				
3.		**1**		
Average				
Acceptable *				
*	**Variation in output/mAs < ±10% from the mean**			

6	HALF VALUE LAYER (HVL)	
Kvp: 28	**Target/Filter: Mo/Mo**	**mAs: 12**
No.	Added Filters (mm Al)	Reading
1.	**0**	
2.	**1**	
3.	**2**	
4.	**3**	
5.	**4**	

6.	**5**	
HVL		
Acceptable *		
*	**HVL > 0.3 mm Al and < 0.4 mm Al**	

7	MEAN GLANGULAR DOSE TO STANDARD BREAST	
Using clinical exposure setting for 5.3 cm beast (after exposure of 4.5 cm PMMA block under AEC)		
Kvp	**mAs:25**	**Target/Filter:MO**

No.	**Kair (mGy)**
1.	
2.	
3.	
Average	
MGD	
Acceptable *	
*	

8	ALIGNMENT OF X-RAY FIELD TO IMAGE RECEPTOR				
Using two loaded cassettes (one in the Bucky tray and other on top of the breast support table) and two x-ray absorbers.					
FFD	Front edge (mm)	Back edge (mm)	Left edge (mm)	Right edge (mm)	* Acceptable
*	**< 5 mm overlap or no any visible undercoverage**				

9	UNIFORMATY

Expose to give OD of 1.0 to 1.5 above base + fog level.			
OD_1 (10 cm from OD_2 LHS)	OD_2 (4 cm from chest wall on midline)	OD_3 (10 cm from OD_2 RHS)	* Acceptable
0.3			
*	**< 0.15 OD between points and no any significant artifacts.**		

10	STANDARD FILM DENSITY		
4.5 cm PMMA block exposed under AEC.			
Kvp:	**mAs:**	**Target / Filter:**	
OD		* Acceptable	
*	**Within the range of 1.5 to 1.9.**		

11	AEC DEVICE & BREAST THICKNESS COMPENSATION				
Positioning: AEC chamber in chest wall position. 2 …. 7cm PMMA blocks exposed under AEC.					
PMMA Thickness (cm)	mAs	Kvp	Target/Filter	OD or O/P	* Acceptable
2					
3					
4					
5					
6					
7					
*	**OD < ± 0.2 OD from standard film density (4 cm), or density range < 0.3 OD, or densities within range 1.3 to 2.1.**				

IMAGE QUALITY EVALUATION:

TOR MAM:

Exposure factors (under automatic exposure control)			kVp :28 mAs :	
Background densities		filaments	particles	Circular details
B1:	B2:			
* Acceptable				
*	**B1& B2:OD ± 0.20**			

DENSITY MEASUREMENTS (TOR MAX)	
Mean Background Density	
High density point	
Base +fog test point	
Scatter(4)-(3)	
Speed index	
Contrast index (2-6)	
Visual contrast(one –(6))\(1)	

UNSHARPNESS MEASUREMENTS (TOR MAX):

Resolution limit	RHS Grating	Groups	Line pairs \mm	* Acceptable
	LHS Grating			
		Groups	Line pairs \mm	
Low contrast bar patterns	Groups	Line pairs \mm		
*	**Resolution:11lp/mm in both directions -**			

LOW CONTRAST SNSITTIVITY (TOR MAX):

6 mm circular details	No. detected	Threshold contrast

Small detail visibility (TOR MAX):

	No. detected	Threshold contrast
0.5 mm details		
0.25 mm details		

Micro Particle step wedge:	Comment:

7	MEAN GLANGULAR DOSE TO STANDARD BREAST		
Using clinical exposure setting for 5.3 cm breast (after exposure of 4.5 cm PMMA block under AEC)			
Kvp		**mAs:25**	**Target/Filter:MO**
No.	**Kair (mGy)**		
1.			
2.			
3.			
Average			
MGD			
Acceptable *			
*			