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Estimation of Radiation Dose During Mammographic Procedure

تقدير الجرعة ألأشعاعية أثناء إجراء التصوير الشعاعي للثدي

Thesis submitted for partial fulfillment of M.Sc Degree in Medical Physics

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2020

الأية

(ويسألونك عن الروح قل الروح من أمر ربي وما أوتيتم من العلم إلا قليلا)

سورة الإسراء الأية_85

Dedication

To the purest of two hearts in my life ...

My Kindness father .... the one who taught me how to live with dignity and honor.

My tender mother ...... is the epic of love and joy of life, and an example of dedication and giving.

To my brothers .... support me and my arms and share my joys and sorrows.

To the people closest to myself.

I dedicate to you my scientific research on ...

The acknowledgement

First, all thanks for **Allah** who gave me the health and patience to complete this work.

Offer my thanks to the icon of science, my supervisor,

Dr. Hussein Ahmed Hassan

Thanks are due to Sudan University of Sciences & Technology, for the opportunity to study in.

Thanks to everyone who helped me in completing this work…

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List of Abbreviations

AEC	Automatic Exposure Control
CC	Cranial Caudal
DM	Digital Mammography
ESAk	Entrance Surface Air Kerma
ES	Enteranc Surface Dose
FFDM	Full Field digital Mammography
HVL	Half Value Layer
kVp	Kilo-volt peak(Tube voltage)
mAs	miliampere . second (Tube current. time)
MGD	Mean Glandular Dose
mGY	mille Gray
MLO	Medio-lateral Oblique
SM	Screen Mammography

Abstract

Mammography is the primary imaging tool used to diagnose breast cancer and examine suspicious lesion tissue. Due to the steady increase in the use of mammograms in recent times, the patients and doctors' concerns about the single dose of radiation and the risks from that ionizing radiation have increased.

The aim of this study is to estimate the radiation dose for patients during mammography and to identify the factors affecting the dose.

60 patients were examined using a digital computerized imaging unit in the radiology department under clinically justified conditions in one of the Hospitals in Sudan. According to the protocol used in the department, then two views were made for each patient (CC) and (MLO) after measuring breast thickness and choosing the appropriate exposure factors in each projection automatically, the MGD was extrapolated it is the most sensitive tissue in the breast.

In this study, the descriptive and analytical approach was used through the SPSS program and the results showed that, (MGD) (mGy) (1.6822 ± 0.6681), exposure factors used: two values for (kVp) (25, 26) and two values for (mAs) (50, 130). The results indicate that the radiation dose values in this study did not exceed the value specified by the Food and Drug Administration (3.0) (mGy), also there is a significant correlation between (kVp) (mAs) and (MGD).

Low doses indicate that the radiation generators in this unit are able to achieve acceptable levels of dose, But there is a portion of patients whose results are normal, so an accurate justification is required for the examination. Also use two values for (kVp) did not clearly explain the form of the correlation between (kVp) and (MGD), Therefore, several kVp ratings can be tested to explain this relationship.

مستخلص

التصوير الشعاعي للثدي اداة التصوير الأولية المستخدمة في تشخيص مرض سرطان الثدي وفحص الأنسجة والأفات المشبوهة. نسبة للزيادة المطردة في استخدام الماموغرام في الأونة الأخيرة، أزدادت مخاوف المرضى والأطباء إزاء جرعة ا لإشعاع الفردية والمخاطر الناتجة عنها.

الهدف من هذه الدراسة تقدير الجرعة الأشعاعية للمرضى أثناء إجراء التصوير الشعاعي للثدي والتعرف على العوامل المؤثرة على الجرعة. تم الفحص ل ٦٠ مريضة بإستخدام وحدة تصوير رقمية محوسبة في قسم الأشعة تحت ظروف سريرية مبررة طبيا بأحدى المستشفيات بالسودان. وفقآ للبروتوكول المستخدم في القسم تم إجراء إسقاطين لكل مريض (CC)و(MLO) بعد قياس سمك الثدي و أختيار عوامل التعرض المناسبة في كل أسقاط أليآ ،وتم أستقراء متوسط الجرعة الغدية إذ تمثل الأنسجة الأكثر حساسية للأشعاع في الثدي.

في هذة الدراسة تم أستخدام المنهج الوصفي و التحليلي عبر التحليل الإحصائي spss و أظهرت النتائج أن متوسط الجرعة الغدية (MGD) (mGy) (١.٦٨٢٢± ٦٦٨١.) وعوامل التعرض المستخدمة : قيمتان ل (kVp) (٢٥،٢٦) وقيمتان ل(mAs)(٥٠،١٣٠) ، تشير النتائج الى ان قيم الجرعة الأشعاعية المسجلة في هذه الدراسة لم تتعدى القيمة المحددة من قبل منظمة الغذاء والدواء(mGy) (٣.٠) كما دجوي أرتباط كبير بين عوامل التعرض (kVp) ، (mAs) ومتوسط الجرعة الغدية (MGD) .

يشيرإنخفاض الجرعات الى أن مولدات الأشعة السينية في هذه الوحدة قادرة على تحقيق مستويات جرعة مقبولة لسلامة المرضى ، لكن هنالك جزء من المرضى كانت نتائجهم عادية لذلك مطلوب مبرر دقيق لإخضاعهم للتصوير ،كما ان استخدام قيمتان ل (kVp) لم يفسر بوضوح شكل الارتباط بين تيار الانبوب ومتوسط الجرعة الغديه لذلك يمكن اختبار عدة تدريجات لتيار الانبوب لتفسير هذة العلاقة.

Chapter one
Introduction

1.1 Introduction:

Mammography refers to an x-ray examination specially designed to detect human breast diseases and has been in use since the 1960s, and it is nowadays the most effective and accurate method for early detection of breast cancer. Breast cancer is the most common type of cancer among women around the world (Parkin et al., 1984). Breast cancer incidence increases rapidly with age, rising sharply until menopause and less rapidly or not rising at all after that. There is a big difference in breast cancer rates between different countries. Around the 1990s, the incidence of breast cancer varied 10-fold worldwide, indicating important differences in the distribution of the underlying causes (Barkin et al., 2001). Mammogram machines have witnessed a great development in the techniques used in mammography to diagnose problems more accurately, which has made their use wandering widely in recent years. Unfortunately, improving the quality of medical images always means increasing the patient's radiation dose, so an increase in the use of ionizing radiation during imaging increases the potential for health risks if it is not used or contained properly. Cancer detection is based on the difference in X-ray attenuation coefficient between normal and diseased tissues (J. T .Bushberg et al., 2001). And according to any examination that includes x-ray images, there is always a small random risk of cancer (L. Magnus et al., 2015). It is therefore important to assess the risks of the dose being delivered to the patient during the screening process, in other words, to keep the dose as low as it can reasonably be achieved (M.

Zeidan, 2009). Any proposed activity that may cause exposure to radiation must provide sufficient benefit to society to justify the risks to radiation exposure. "This statement, known as the ALARA principle, is particularly valid in breast cancer screening. Dosimeters and patient dosage are important considerations in radiography and especially in mammography. In general, when discussing radiation dose, it is necessary to review some quantities and units of measurement: kirma air it is the amount of radiation sometimes used to express the concentration of radiation that is delivered to a point, such as the surface of a patient's entrance (S.C. Bushong, 2001). Entry surface dose (ESD) is an important parameter for evaluating the dose a patient receives in a single radiographic exposure (G. Compagnoe et al., 2005). Average glandular dose (MGD) is the volume that best describes the amount of risk to glandular tissue resulting from the use of radiation in mammography (F. Bouzarjomehri et al., 2006). The standard mammography protocol for screening always includes two views, the craniofacial (CC) and the mean lateral oblique (MLO). The 45 ° angle is usually appropriate for the majority of patients in routine daily practice (F. Bouzarjomehri et al., 2006). There are two types of mammography - screen mammography (SFM) and digital mammography (DM). This study aims to estimate the radiation dose delivered to the patient during the mammography process and the study factors that affect the dose delivered by mammography.

1.2 Problem of study:

During the mammography examination, the patient exposed to dose of radiation. Some values recorded during the examination sometimes exceed the values specified and agreed upon by international organizations for the patient safety.

1.3 General objective:

The general objective of this study is to estimation of radiation dose during mammographic procedure.

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1.4 Specific objective:

- Estimation of average glandular dose during diagnostic mammography.
- Evaluation of factors affecting the average glandular dose.

1.5 Overview of study:

This study consisted of five chapters, with chapter one is an introduction, it presents the statement of the study problem, objectives of the study and significant, chapter two included literature reviews previous study and background, chapter three described the exact methodology (material, method) used. Chapter fourth includes result presentation and finally chapter five contains the discussion, conclusion and recommendation for future scope in addition to references and appendices.

Chapter Two

Theoretical Background and Literature Review

2.1 Breast anatomy:

The human breast is comprised of several types of soft tissue, each with varying densities, which presents some unique imaging challenges. The main structure is the mammary gland, which consists of 15 to 20 lobes, each with numerous related ducts and lobules. The individual lobes of the mammary gland open into the lactiferous ducts, all of which converge at the nipple. The body of the mammary gland is imbedded within fatty tissue, is supplied by a network of blood and lymph vessels, and is supported by connective tissue. Furthermore, the range of tissue densities is even greater with malignant breast tissue. Both the radio-dense tissue (e.g., fibrotic tissue, glandular tissue, and malignant tissue) and radio-lucent tissue (e.g., fat or loose connective tissue) must by clearly visible on the mammogram so that the radiologist can make accurate diagnoses. To image all of these tissues properly, a mammography system must provide very low KVp techniques, in the range of 20-40 KVp, at relatively high mA/ mAs outputs. In addition, extremely small focal spots (0.1-0.3 mm) must be used to image the very fine micro-calcifications. This fatty layer has another function, is to replace the fabric the glandular, which is atrophies after menopause, where these fats are spreads from the base of the breast towards the nipple (Joseph J. Panichello, 2017).

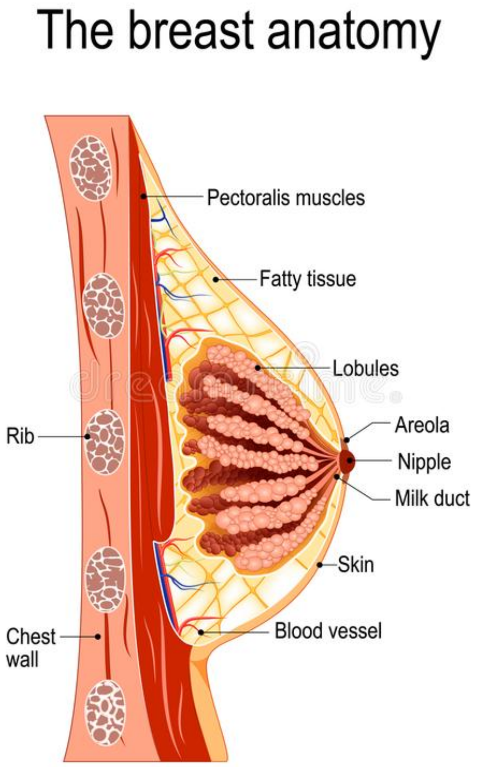


Figure 2.1 Breast anatomy

https://thumbs.dreamstime.com/b/breast-anatomy-cross-section-mammary-gland-vector-diagram-medical-use-107519344.jpg

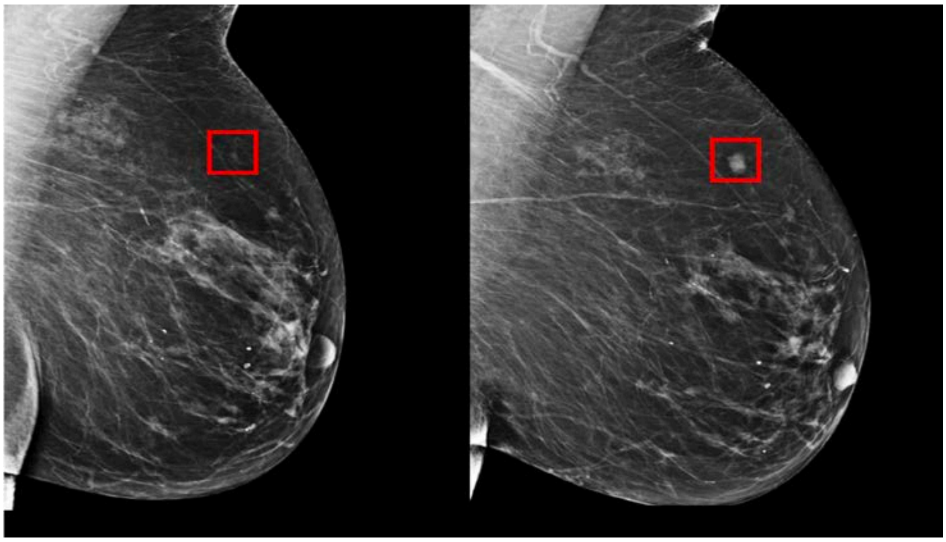
2.2 Breast cancer:

Breast cancer is the most common cancer of women worldwide. There have been sustained increases in the incidence of this cancer in developing countries in recent years. Breast cancer accounts for 22% of all female cancers, which is more than twice the occurrence of cancer in women at any other site. Male breast cancer is rare compared with female breast cancer (Gianni, 2013).

cancer cells are abnormal cells that grow and multiply uncontrollably and form tumors. The tumor usually begins from the outer upper quadrant of the breast in the cells of the ducts that produce milk, then begins to spread on the ligaments and adjacent tissues, and may extend towards out to the skin forming a scar (emphysema or lump).

Recent studies have shown that Sometimes cancer cells can spread through the body (through the lymph apothecary or blood flow) to invade other organs and form new tumors.

Breast cancer occurs when some cells begin to grow abnormally as result of a mutation or change in genetic material, and then spread to the rest of the breast and lymph nodes, and from there to other parts of the body. The early observation of this disease during its early developments is a critical factor in the success of treatment, and this is what the mammography device provides it to distinguish between diseased and healthy tissues(Gianni, 2013).



figuree 2.2 image for Breast cancer during mammography

https://techcrunch.com/wp-content/uploads/2019/06/BreastCancerAI.png

2.3 Mammography:

Mammography is radiographic imaging of the breast it used as a tool for diagnosis and examination. It has proved to be of great importance in the detection of breast cancer early and reducing the mortality rate from it by detecting special tumor or small calcifications; and diagnosis of breast diseases in women. A mammography exam, it's called a mammogram. Mammogram is one of the types of diagnostic imaging devices using low-dose x-ray (usually about 0.7 m Sv) to be examined human breast; each breast is photography with two different faces for a complete analysis. The examination will be observe through breast tumors without exposing the patient to a radiation dose high, because the breast is very sensitive to ionizing that may cause a tumor in the breast. There are two types of mammogram tests for early detection of breast cancer, the first type is the standard mammogram screening device, and the second type is a digital mammogram screening device, and both types have the same accuracy and work almost as efficiently. The standard mammogram test is the most common and provides still images of the breast and its tissues, while digital mammogram scans provide images of the breast from different sides and methods and are transmitter on the computer where the screening device is connect to digital receivers and computers. Although the standard mammogram and digital mammogram scanner work with the same efficiency, the digital mammogram scanner contributes to providing a better image and therefore greater accuracy in the early detection of breast cancer, especially in young women and women who have much breast tissue.

2.4 Digital Mammography:

One of the most important developments in this field is the digital mammography, which is known as the full field digital mammography

(FFDM). Digital mammography used in routine screening of asymptomatic women, it has been shown to contribute to reduced mortality. It is still the most widely used imaging technique for detecting breast cancer and has the advantages of being relatively inexpensive and accessible (IAEA, 2011).

And it is based in essence on the same principle as the traditional mammography, but this system is equipped with a digital future that converts x-rays into electrical signals instead of drenched. The ones in the cassette use these electrical signals to produce a picture of the breast, which can be seen on a surveillance screen or print on special film

In this technique uses the possibilities of the computer of storing the image in his memory, restoring it on demand, enlarging images and writing on it at the discretion of the radiologist, acquiring images faster and less time. However , this technology was developed to overcome some of the difficulties facing the technology, including improving the display range, flexibility in adjusting the brightness and contrast of the image, noise, and better control of the use of accident radiation dose.

2.5 Mammography Unit:

The mammogram is a rectangular box containing an X-ray tube, Consists mainly of an electronic section, a mechanical section and an x-ray section.

This device differs from conventional radiography devices using a low-energy radiation beam and the ability to produce an image with high accuracy and clarity. And this device is used in mammography only; because it is equipped with some completes that allow only photography of the breast at different angles (Joseph J. Panichello, 2017).

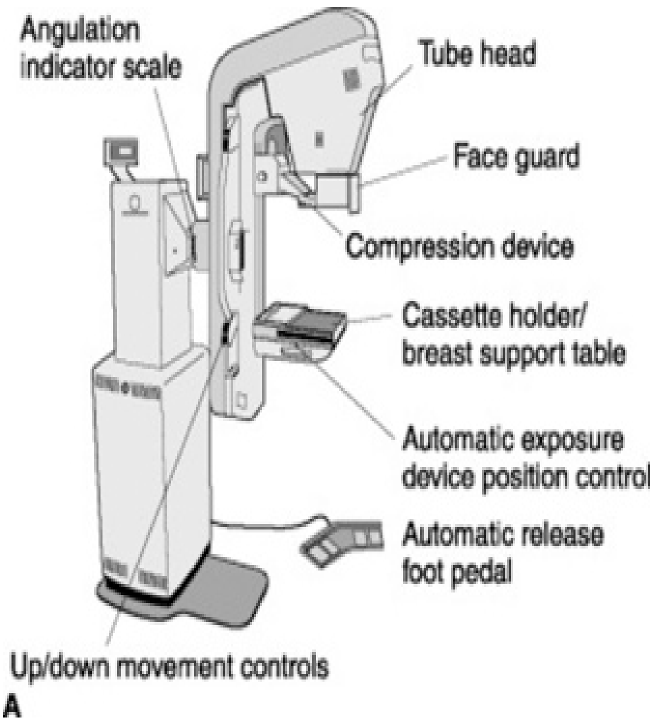


Figure 2.3 Mammography Unit

https://radiologykey.com/wp-content/uploads/2016/02/B9780443104190000152_gr5.jpg

2.5.1 X-ray tube:

The x-ray tube is a traditional type tube that emits X-rays, it carried on a rotatable arm; it is the main component of the system and responsible for generating, X-ray package used in the imaging process, The x-ray tube in the digital mammography unit is specially designed with capabilities that serve satisfactorily diagnosing and examining the beast as the focal range is relatively small compared to those used in other imaging systems and also with an exit window usually of beryllium(Be), target materials, appropriate x-rays and ray filters. The function of these filters is to obtain on the appropriate radiation spectrum, in addition to a high compression device with a detector with dimensions large enough for mammography (IAEA, 2011).

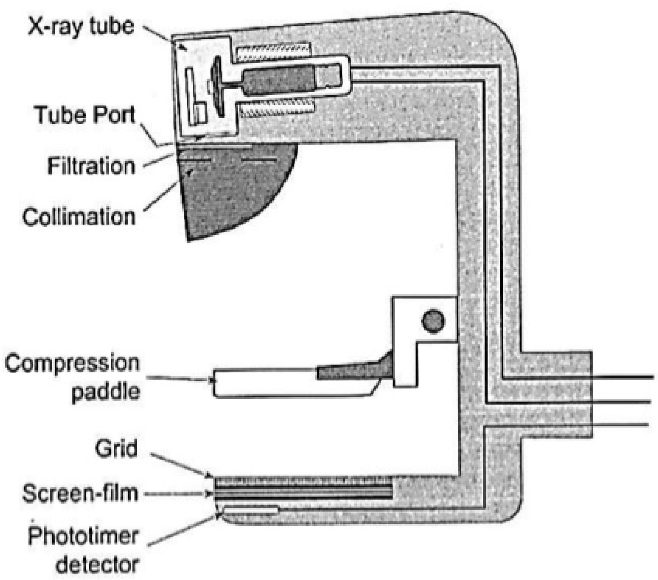


Figure 2.4 components of X-ray unit

https://image.slidesharecdn.com/mammography2-150601213335-lva1-app6891/95/mammography-10-638.jpg?cb=1433194627

2.5.1.1 Grid:

A metal plate (grid) is placed between the breast and the film consisting of a number of thin strips of carbon fiber placed in parallel, as the height and width of these slices are designed to absorb the reflected rays returning from the metal part of the device without affecting the main beam emitted from the source, allowing it to pass through to photography from breast to the film, And it has started using oscillating grid to eliminate the steps of the grids affecting the quality of the images through their movement (Joseph J. Panichello, 2017).

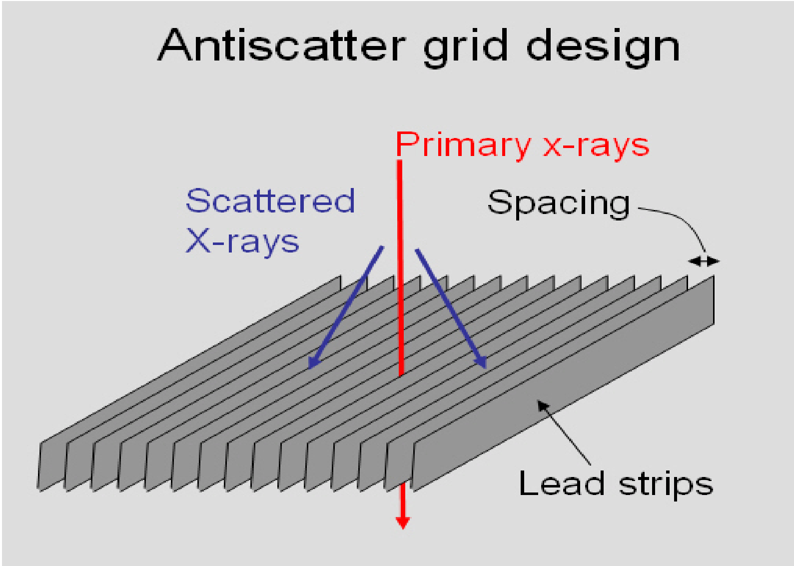


Figure 2.5grid design

https://www.upstate.edu/radiology/images/education/rsna/radiography/grid_design.jpg

2.5.1.2 Focal spot Consideration:

The important feature of mammography x-ray tubes is the use of a very small focal spot size, which is required to image the micro calcifications and fibrotic strands in the breast. Common focuses used in mammography range from 0.1 mm to 0.3 mm. These focuses are very small in comparison to those used in general radiography, which usually range from 0.6 mm to 1.5 mm.

2.5.1.3 Filters:

When producing an x-ray spectrum with sufficient properties to produce a mammography image, another additional, low-energy X-ray spectrum comes out from the tube outlet, which does not contribute to the production of the image, so the use of filters is necessary to avoid these spectra from reaching the patient. Most mammography units use a set of different filters so that the operator can switch them automatically from the operator's workstation. The reason for the multiplicity of filters is the difference in breast tissue from one patient to another due to the age and condition of the patient. Usually, in mammography, molybdenum (Mo) is used as a filter in the case of small to normal-density breasts, and radium (Rh) as a filter in the case of large or dense breasts, especially when higher effort is required. Moreover, both filters prevent low-energy X-ray components (Joseph J. Panichello, 2017).

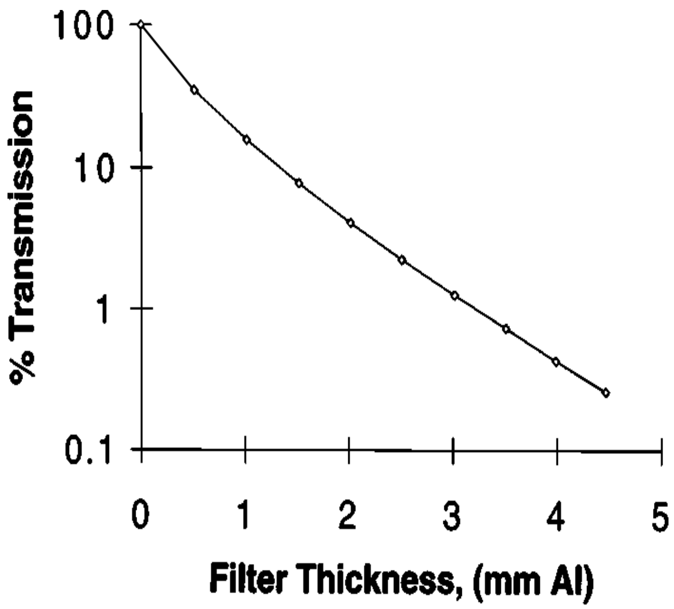


figure2.6

Transmission-measurements-made-with-mammography-x-ray-unit https://www.researchgate.net/profile/Nina_Lee14/publication/341026574/

2.5.2 Compression device:

When performing a mammography, we need to produce a diagnostic quality image of the breast tissue. Breast compression contributes to improving image quality and the compression device works to stabilize and spread the fibrous glandular tissue in the breast and reduce the total thickness so that the radiation beam passes through less tissue, which reduces the amount of exposure and thus reduces the dose As a result, the image is improved to facilitate vision through the breast tissue. There are many other benefits of the compression process, when compression the breast, healthy tissues spread and the lesions and changes hidden by the surrounding tissues are easily detected, and there is a clear view of the calcifications arising between the tissues and it works on consistency. Thickness, reduced movement and suppression of arterial pulses, leading to reduced noise and better suitability for exposure in film width. The mammography units provide manual and automatic tissue compression. Mechanical compression is initiated either by a footswitch located at the base of the gantry or a switch in the arm and the paddle is automatically lowered down or by manually rotating the pressure knob until the required amount of pressure. The compression device consists of a compression motor, a compression cart, and a compression paddle. The compression force can be adjusted automatically in the range of (15-30) pounds, while the maximum compression reaches 65 pounds (Joseph J. Panichello, 2017).

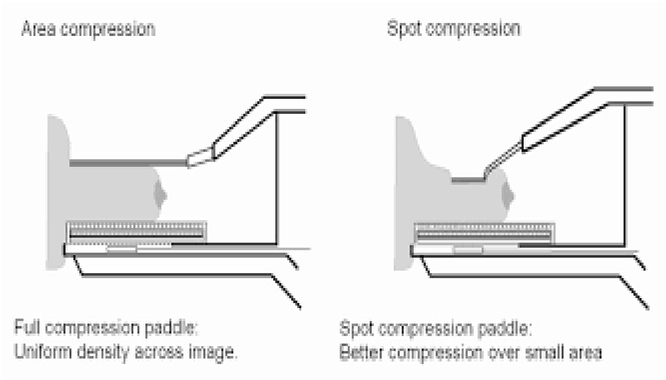


Figure2.7 compression paddles

https://encrypted-tbn0.gstatic.com/images?q=tbn%3AANd9GcScrnz6gg6fLxdPwuA9lpP-NJT58zuPE4zyQg&usqp=CAU

2.5.3 High voltage generator and console:

The generator converts the value and shape of the voltage and the current inside the mechanism to the current needed to generate electrons and the high voltage needed to accelerate them in the tube this generator is of the high frequency type i.e. converts the frequency from 50 or 60 Hz to 100 KHz or of the fixed voltage type.

The goal of using high voltage is to bring the high voltage form applied to the tube close to the ideal state which is the case of Dc. Must provide the high voltage generator with an effort value ranging from 20 to 35 KVp. And this voltage must be changed according to small gradients in order to be able to get the most accurate result possible, as well must be shooting time ranging from 0.01-6 seconds. Most of the radiation equipment, including the mammography device, is equipped with the advantage of automatic exposure to radiation that is by adding a radiation sensor placed behind the film on the opposite side of the radiation tube. Which stops the generation of radiation as soon as it is sensitive to the occurrence of X-ray photons on it, and thus reduces the radiation dose and also reduces the amount of radiation dropped on the film. In addition, the sensors used in this area are hard sensors and photoelectric amplifiers.

2.5.4 Image output section:

The image is generally displayed on the screen in the electronic display section and this section mainly consists of an electronic enhancement element called CCD, which is a matrix containing a large number of light-sensitive elements and a resolution level of up to 1024 X 1024 pixels, this element converts the x-ray photon that falls on it to an electrical signal so that these photons generate an electrical charge on each element of the matrix according to the strength of the photon, and it is stored on the computer and then processed to obtain an image that is displayed on the screen. This device allows to adjust the image, which increases its accuracy and that is one of the most important features of the display in this section, On the other hand, in contrast to the image in the traditional technique of mammography, where the x-ray fall on the tuber with phosphorescent crystals in the film holder, which in turn emit photons responsible for creating images on the film (IAEA, 2011).

2.6 Mammography views:

As a rule, a routine mammographic screening examination requires minimum of two exposures per breast. All exams should include imaging in two planes: the Mediolateral Oblique view (MLO) and the Cranial Caudal view (CC).

With these two standard views, the radiologist should have enough visualization of tissue to provide reliable diagnoses of breast abnormalities. Additional views should be used only when standard views are inconclusive. Some additional views include a spot compression view, a magnification view, a 90 –degree lateral view, and rolled view. The MLO projection is performed at a 30 degree to 70-degree inclination from the vertical and provides good visualization of the entire breast. Most carcinomas can be identified in this view. The MLO view is supplemented with the CC view, which allows full visualization of the entire body of the mammary gland. In a CC view, the x-ray tube is positioned directly overhead, with the beam traveling from superior to inferior. Tissue compression is used with all procedures, With standard view, the compression paddle must match the size of the image receptor and full field collimation is utilized to image the entire breast. However, occasionally there is a need to spread a small area of the breast tissue to help differentiate superimposed structures. In this case, spot compression is used. The compression paddle (or cone) used in spot compression is much smaller than a standard compression paddle, measuring as small as 7 cm. In addition, spot compression is performed with the x-ray beam collimated down to the area of interest only (Joseph J. Panichello, 2017).

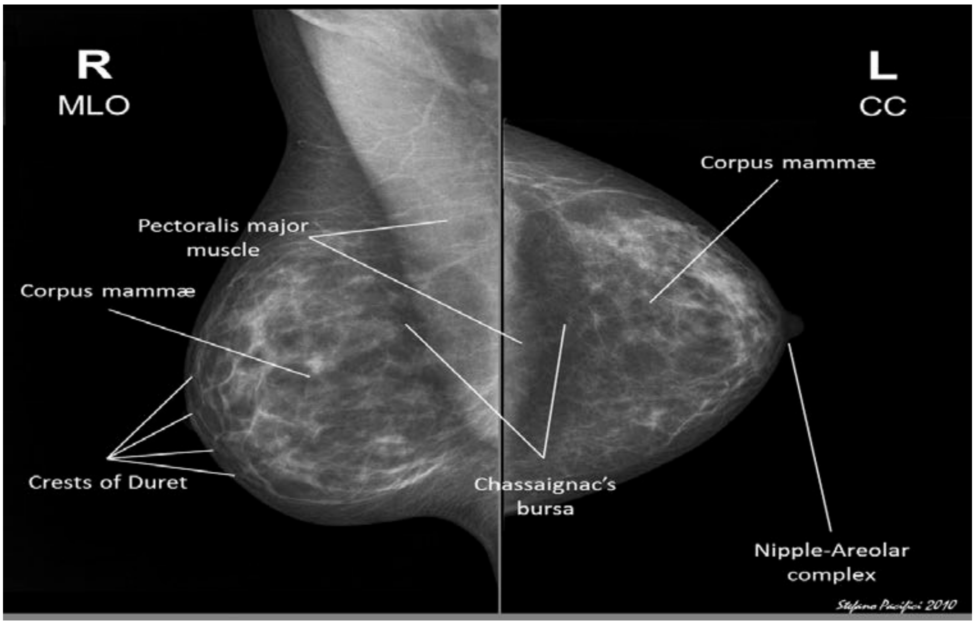


Figure2.8 CC and MLO views in mammogram

https://prod-images-static.radiopaedia.org/images/5040918/7619287b4bf54b031335c25cca3220_jumbo.jpeg

2.7 Half value layer:

Half-value material layer (HVL), is the material thickness at which the intensity of the incoming radiation is reduced by half. HVL can also be expressed in terms of air grapevine rate (AKR) "The radiation beam is attenuated to the extent that the AKR is reduced to half of its original value." In this definition, the contribution of all scattered radiation, except for any beam initially present is considered in the respective package, excluded. This applies to narrow beam geometry only because the wide beam geometry will experience a large degree of dispersion. (HVL) is an important indicator in calculating average glandular dose and assessing radiation risk in mammography. Low HVL indicates low photon energy. HVL is measured in millimeters of aluminum. After filtering by one HVL, the subsequent HVL will be higher because the filtered photons have a higher energy (thicker material is required to dilute half of the penetrating beams) as HVL correlates with the mean free path.

The HVL required for mammography ranges from 0.3 mm to 0.5 mm of aluminum, vs. 3.0 mm to 5.0 mm of aluminum used for general radiography (Joseph J. Panichello, 2017).

(HVL) is related to the attenuation factor of linear (μ) with the following formula:

$$HVL = 0.693 / \mu$$

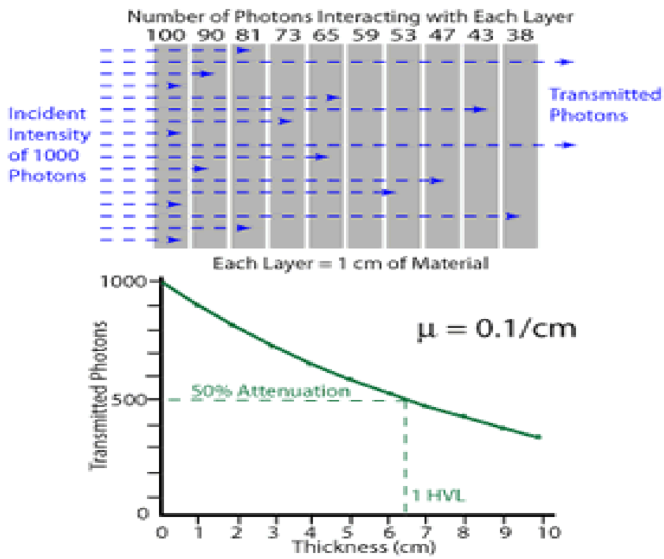


Figure2.9Transmitted photons through each layer of material

https://www.nde-ed.org/EducationResources/CommunityCollege/Radiography/Graphics/Attenuation.gif

2.8 Automatic exposure control:

The use of manual selection of exposure technique factors sometimes results in poor exposures that ultimately affected the image on the film. The problem is solved with the use of automatic exposure control (AEC) in which a the design of automatic exposure control in digital mammography units differs from that in analog radiography. In general, digital systems choose the appropriate and more penetrating x-ray spectra automatically, as a larger dose of the detector can be used and thus the doses are widely varied according to need and according to breast thickness. Moreover, it is used in the automatic exposure system to measure the thickness of the breast compression by a sensor in the design of automatic exposure control in digital mammography units differs from that in analog radiography. In general, digital systems choose the appropriate and more penetrating x-ray spectra automatically, as a larger dose of the detector can be used and thus the doses are widely varied according to need and according to breast thickness. Moreover, it is used in the automatic exposure system to measure the thickness of the breast compression by a sensor in the compression mechanism to select some technical parameters such as (kV, target, filter) to be used in the patient's exposure during the examination. Despite these features in this technology, Despite these advantages in this technique, sometimes the exposure rate for the patient increases with increasing the dose beyond the ideal image (image with limited noise), which greatly improves image quality, but this may lead to an overdose that exceeds exposure levels idealism (IAEA, 2011).

2.9 Patient position:

Breast positioning is key factor affecting a mammography and the resulting clinical image of the breast, where the optimal position increases the amount of breast tissue visible on the image. In mammography, the breast is placed in a natural anatomical position where the nipple perpendicular to the chest wall and this is applied to all procedures of examination, Careful attention can be performed during the patient's placement to avoid artificial movement of breast tissues and periodic breathing movements to maximize imaging of tissues and avoid overlapping structures.

2.10 Entrance Surface Air Kerma (ESAK, mGy) calculation:

The entrance surface air kerma is the kerma air measured on the central beam axis at the position of the patient surface, It is the practical quantity chosen to estimate breast tissue doses during mammography, as it is measured for each projection for each procedure. The radiation incident on the patient and the back scattered radiation are included. the unit of kerma is gray (ICRP, 2019). The entrance air kerma is related to the incident air kerma by the back scatter factor, B, thus:

$$K=k_i. B$$

(k_i**)** the incident air kerma, **(**B**)** the back scatter factor.

2.11 Mean Glandular Dose (MGD) calculation:

The average glandular dose is used for x-ray dosimetry and is an amount used to describe the radiation dose absorbed during a mammogram. According to the fact that glandular tissues are the tissues most sensitive to radiation, most malignant infections are believed to arise in them, so it is a measure of the potential risks when exposed to ionizing radiation.

Glandular tissue is part of the group of breast-forming tissues, with the total amount and spatial distribution of tissues completely variable among women. Despite the intrinsic uncertainty in the glandular distribution, average glandular tissue dose (MGD) has been proposed as a limiting factor for the deleterious calculation. MGD is estimated indirectly from ESAK and Half-Value Layer (HVL). Conversion factors have been proposed to relate the incident radiation to MGD. They are based on breast models, and more specifically, breast shape, compressed breast thickness, and the amount and distribution of glandular tissue. Therefore, MGD is extrapolated using ESAK and the conversion factor is based on Monte Carlo calculations of standard breast projections (A. sulieman, 2018).

$$MGD\ (mGy) = K\ g\ c\ s$$

K (mGy) is the incident air kerma. (g) is a conversion factor that describes the 'K' fraction that is absorbed by the glandular tissue in the breast, assuming the breast is 50% fat and 50% is a gland. (c) is the correction factor for breast formation (i.e. it corrects any difference in glands from 50%). (s) is an X-ray spectrum correction factor that corrects for differences in the X-ray spectrum when using a target / filter combination other than molybdenum / molybdenum (Young, 2014).

x-ray spectra used for calculations of additional s-factors

Target	Filter	(kV)	(mm Al)
W	50 μm Ag	25–40	0.49–0.71
W	55 μm Ag	25–40	0.52–0.74
W	60 μm Ag	25–40	0.54–0.77
W	65 μm Ag	25–40	0.55–0.78
W	75 μm Ag	25–40	0.59–0.82
W	0.5 mm Al	25–40	0.36–0.62

Figure2.10

value of s factor for different mammographic target/filter combinations.

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

* Data taken from Dance et al. [8.20].

Figure2.11Data taken from Dance et al to value of s factor for different mammographic target/filter combinations

2.12 Cancer risk estimation:

Assessing the risks from exposure to radiation during a mammography procedure is central to recommendations ICRP.

The probability of cancer risk and tissue reaction to radiation depends on the dose value and tissue sensitivity rates (ICRP, 2007). Any dose can cause effects as there is a linear response between the dose and the increased risk potential (the central assumption for the linear relationship between dose and response to cancer and genetic influences is about 5% per Sv as an increase in dose leads to a proportional increase in risk even at lower doses(ICRP, 2007)). The effective radiation (E, mSv) is the quantity chosen to express the probability of developing cancer (the effective dose value in the cases of planned exposures should not be exceeded and is specified for the reference person, using the results of individual monitoring of the agent and the ICRP reference (ICRP, 2007). It is a stabilized dose using the equivalent dose (mSv) multiplied by tissue weight factors (W_t).

2.13 previous studies:

(William. et al, 2017) A prospective and descriptive study carried out over a 12 months period in the University College Hospital (UCH), Ibadan. Ethical approval for the study was sought and obtained from the joint University of Ibadan/University College Hospital UI/UCH institutional review board. Four hundred and twenty-seven consecutive women who presented to the radiology department for screening mammography were enrolled into the study after obtaining their consent to participate in the study. Mammographic study was performed on all the women in the Department of Radiology of the UCH, using a GE senographe DMR mammography machine. Each subject received two standard views; cranio caudal (CC) and medio lateral oblique (MLO) for the screening mammography. Women for diagnostic mammography were excluded from the study as they required additional views that would affect the total radiation dose received. MGD was counted for 427 patients. The MGD contribution from projecting MLO for a given patient was higher than that of projecting CC due to the higher mAs used in projecting MLO. A weak but positive correlation appears between compressed breast thickness and applied mAs, ((R (Bushberg et al., 2002) 0.4618). There is little difference in applying voltages to all women with respect to compressed breast thickness, with no significant correlation showing. By comparing MGD and mAs applied, There is a fairly strong and positive correlation (R2 0.5825). The average dose per film was 1.7 (1.2, 2.4) mGy MLO view and 1.4 (1.1, 2.0) mGy for CC display. The average dose each woman had 1.8 (1.3, 2.5) milligrams for the one-point scan and 3.3 (2.3, 4.6) mGy for dual-width test. Dosage per movie Show an exponential relationship to breast thickness. The mean MGD per film was 2.63 (0.9, 6.45) mGy and 2.12 (0.19, 5.42) mGy for MLO and CC predictions, respectively. The values were for breast thickness and dose Consistent with those in other published surveys.

(Sulieman, et al., 2018) The aim of this studywere to quantify radiation doses arises from patients' exposure in mammographic X-ray imaging procedures and to estimate the radiation induced cancer risk. Sixty patients were evaluated using a calibrated digital mammography unit at King Khaled Hospital and Prince Sultan Center, Alkharj, Saudi Arabia. The average patient age (years) was 44.4 ± 10 (26–69). The average and range of exposure parameters were 29.1 ± 1.9 (24.0–33.0) and 78.4 ± 17.5 (28.0–173.0) for X-ray tube potential (kVp) and current multiplied by the exposure time (s) (mAs), respectively. The MGD (mGy) per single projection for craniocaudal (CC), Medio lateral oblique (MLO) and lateromedial (LM) was 1.02 ± 0.2 (0.4–1.8), 1.1 ± 0.3 (0.5–1.8), 1.1 ± 0.3 (0.5–1.9) per procedure, in that order. The average cancer risk per projection is 177 per million procedures. The cancer risk is significant during multiple image acquisition. The study revealed that 80% of the procedures with normal findings. However, precise justification is required especially for young patients.

(Ogundare, Odita, Obed, & Balogun, 2009) In this work, thermo luminescent dosimeters have been used to measure entrance surface doses (ESDs) of patients undergoing mammographic screening at the University College Hospital, Ibadan, Oyo state. The mean glandular doses (MGDs) were also calculated using the measured ESDs. The results showed that the ESDs ranged from 0.26 mGy to 21.26 mGy for the mediolateral oblique (MLO) views and 0.08 mGy to 5.36 mGy for the craniocaudal (CC) views. The calculated MGD ranged from 0.07 mGy to 3.57 mGy for the MLO views and 0.02 mGy to 0.98 mGy for the CC views. The possible reasons for the large variations in the individual ESD values and MGD values for both views are discussed using patients' data, equipment specific data and the technical parameters used for the examinations. Comparison showed that the mean ESD values and MGD values reported in this work are below published values. The mean of the calculated MGD values is also found to be lower than the recommended guidance level of 3.0 mGy when using grid. 92.5% of the patients had MGD values that are less than 2.5 mGy, hence a national reference MGD value of 2.5 mGy is proposed for Nigeria. Implementation of a dose reduction program in mammographic screening is also suggested because of the observed large variations in patients MGD values.

(Sharif, 2012) The study was conducted at Baghdad Teaching Hospital with the advanced OHO GI device, and it included a number of patients with thick, compressed breasts of 10.9,8,7 cm. The relationship between radiation dose and breast thickness is linear, and when comparing the previously reviewed doses with the atomic energy values and European sources, it was found that they are close. The maximum value of the glandular dose rate 1.45.

Chapter Three
Materials and Method

3.1 Materials

3.1.1 The study population:

The measurement was performed on 60 patients (female) who were examined in the radiology department of Royal Care Hospital in Khartoum, Sudan. All patients underwent the procedure due to medically justified clinical conditions, and the patient demographics were age (years), breast thickness (mm), and radiation exposure factors (kVp, mAs).

3.1.2 Machine:

Radiology department in the hospital where the study was conducted uses a computerized radiograph equipped with an intelligent automatic exposure device that is controlled by a microprocessor supported by the new calibration software ULTRa.

Table 3.1 show the feature of the mammography:

Model	Frequency (kHz)	Power (kW)	X-ray tube potential (kVp)	Focal spot (mm)	Filtration (mm)	Target material
Lilyum	100	5	22-40	0.1-0.3	0.5	Mo/Rh

3.2 Method

3.2.1 Theoretical technique:

The examination was performed after preparing the patient and choosing a comfortable position for him. The breast was placed on the pressure platform and was pressed to a position of suitable thickness. Exposure parameters were chosen according to HVL appropriate to the thickness of the breast. Routine observations are a top-to-bottom view Cranio Caudal(CC) and Mediolateral Oblique (MLO) from the center of the chest to the side of the body using the X-ray tube at an angle. These views are considered standard for the exam. The process was repeated for each patient in determining the position.

The average glandular dose for each view was calculated automatically by a computer program (Excel) that calculates and stores the results of the dose surveys and accordingly according to the total dose for each patient.

3.2.2 Dose measurement:

To calculate mean glandular dose, a linked Microsoft Access database program was used and imaging was required. As the mean glandular dose (MGD) was extrapolated within the made use of ESAK via synthetic agents, the values are tabulated against HVL and the thickness of the constructs.

The glandular metabolism index equation was used by (Dance et al. 2000).

$$MGD\ (mGy) = K.\ g.\ c.\ s$$

K (mGy) is the incident air kerma. (g) is a conversion factor that describes the 'K' fraction that is absorbed by the glandular tissue in the breast, assuming the breast is 50% fat and 50% is a gland. (c) is the correction factor for breast formation (i.e. it corrects any difference in glands from 50%). (s) is an X-ray spectrum correction factor that corrects for differences in the X-ray spectrum when using a target / filter combination other than molybdenum / molybdenum (Young, 2014).

Chapter four
Results

Results:

In this work, results were obtained after performing sixty mammograms. All patients underwent the procedure due to medically justified clinical conditions, whose goal was to detect precancerous lesions in the breast. The selection of patient samples was random in terms of demographic characteristics (age, breast thickness), exposure parameters (kvp, mAs), and patient doses (mGy) are shown in Table No. (4.1). The average patient age (50.08 ± 11.55) (75.0-29.0 years), mean age (50) years according to the sample under study as shown in (Figure 4.1). The mean glandular dose (MGD) (mGy) was (1.682 ± 0.6681) as shown in (Table 4.1), The exposure factors used: two values for (kVp) (25, 26) as shown in(Figure 4.2) and two values for (mAs) (50, 130) as shown in (Table 4.3). In table (4.4) shows that there is a statistically significant linear relationship at the level of significance (b <0.05) or less between (MGD) and the exposure parameters (kvp, mAs) and breast thickness (mm).

Table 4.1 show Descriptive Statistics for all variables:

variables	Mean	Std. Deviation	Min	Max
Age	50.08	11.559	29	75
Tube voltage (kvp)	25.38	.218	25	26
Tube current (mAs)	114.00	32.270	50	130
Breast thickness (mm)	49.92	11.192	16	67
MGD (mGy)	1.6822	.66814	.73	3.09

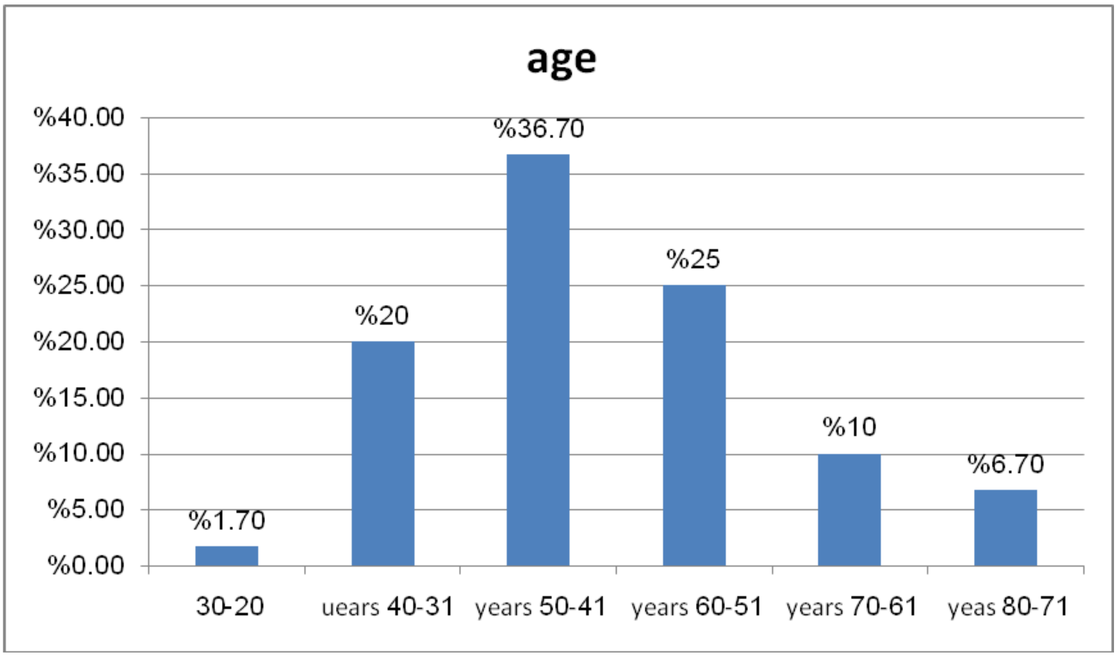


Figure 4.1 Age distribution

Table 4.2 show frequency distribution for Tube voltage

Tube voltage (kvp)	Frequency	Percent
25	15	25.0
26	45	75.0
Total	60	100.0

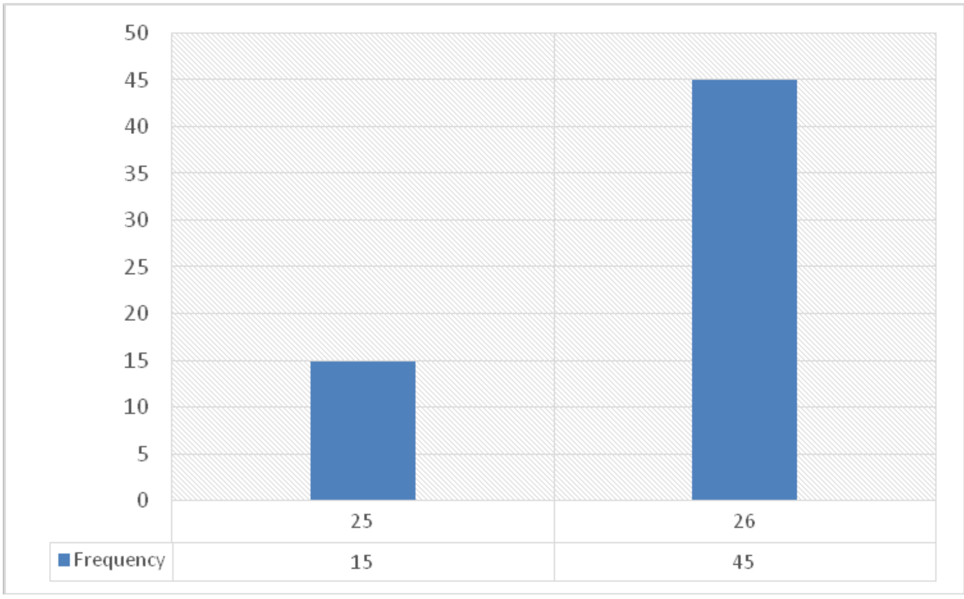


Figure 4.2 frequency distribution for Tube voltage.

Table 4.3 show frequency distribution for tube current:

Tube current (mAs)	Frequency	Percent
50	12	20.0
130	48	80.0
Total	60	100.0

Table 4.4 show correlation between variables:

		MGD	tub	tub current	Breast thickness	age
MGD	Pearson Correlation	1	.081	.435**	-.062-	.037
	Sig. (2-tailed)		.538	.001	.640	.777
	N	60	60	60	60	60
tub	Pearson Correlation	.081	1	-.289*	-.167-	-.006-
	Sig. (2-tailed)	.538		.025	.202	.964
	N	60	60	60	60	60
tub current	Pearson Correlation	.435**	-.289*	1	.286*	.037
	Sig. (2-tailed)	.001	.025		.027	.778
	N	60	60	60	60	60
Breast thickness	Pearson Correlation	-.062-	-.167-	.286*	1	-.144-
	Sig. (2-tailed)	.640	.202	.027		.273
	N	60	60	60	60	60
age	Pearson Correlation	.037	-.006-	.037	-.144-	1
	Sig. (2-tailed)	.777	.964	.778	.273	
	N	60	60	60	60	60

Table 4.5 show analysis of variance for all data with patient's age:

		Sum of Squares	df	Mean Square	F	Sig.
Tube voltage (kvp)	Between Groups	1.321	28	.047	.980	.519
	Within Groups	1.492	31	.048		
	Total	2.812	59			
Tube current (mAs)	Between Groups	27733.333	28	990.476	.911	.597
	Within Groups	33706.667	31	1087.312		
	Total	61440.000	59			
Breast thickness (mm)	Between Groups	4260.767	28	152.170	1.507	.134
	Within Groups	3129.817	31	100.962		
	Total	7390.583	59			
MGD (mGy)	Between Groups	16.890	28	.603	1.979	.033
	Within Groups	9.448	31	.305		
	Total	26.338	59			

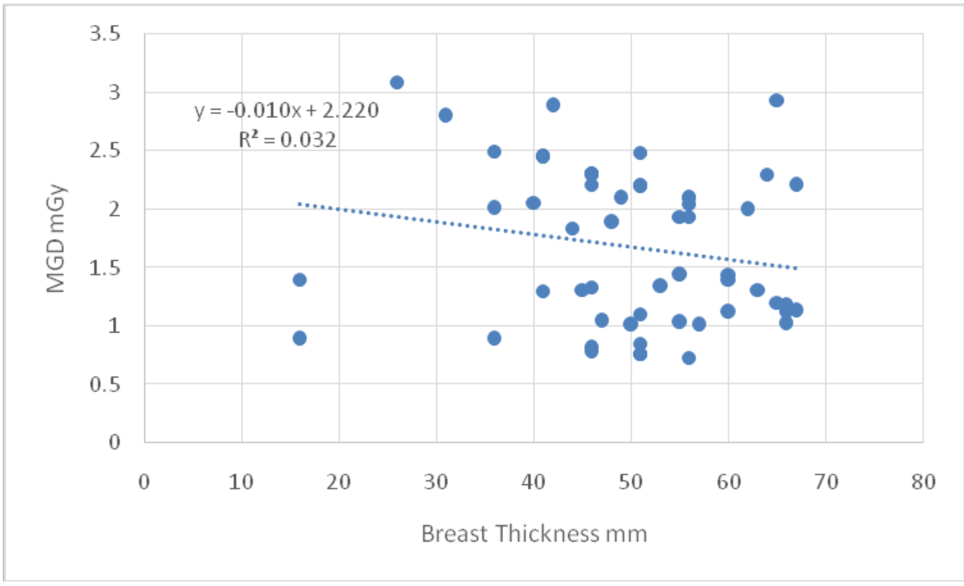


Figure 4.3 show correlation between the MGD with breast thickness

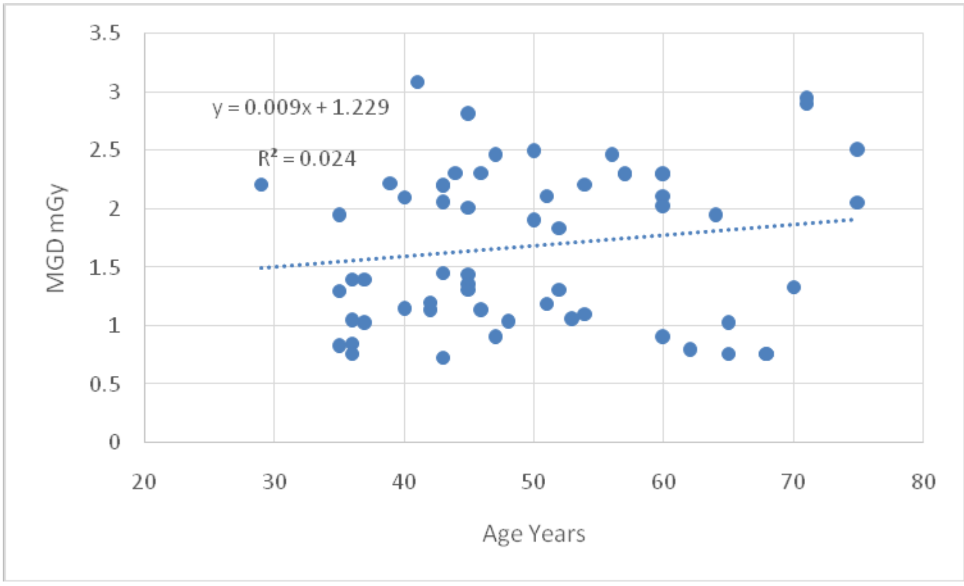


Figure 4.4 show correlation between MGD with patient’s age

Chapter Five

Discussion, Conclusion and Recommendations

5.1 Discussion:

Ionizing radiation resulting from mammography is a source of concern and concern for doctors and the patient himself about the risk of induced carcinogenesis. Therefore, the estimation of the patient's total dose and risk assessment are necessary in developing criteria for justification for conducting the examination based on the analysis of the risk-benefit ratio.This contributes to improving image quality and better control of the factors undergoing screening that ultimately lead to a further reduction in mortality. In mammography, (CC) and (MLO) are used as standard projections for each breast routinely, especially when examining, and there are additional projections that are used when needed, especially in diagnostic mammograms of suspicious lesions. In this study, two projections were used for each breast (CC) and (MLO) according to the routine protocol approved in the radiology department of the hospital where the examination was performed. In this current work, the average glandular dose was (1.6822 ± 0.6681) (mGy), where the largest value for the dose was (3.09) (mGy) as shown in Table (4.1), and it was a single repeat value among the samples examined in this work. However, the average patient radiation dose for each test did not exceed the value specified by the Food and Drug Administration (3.0) (mGy) for projection. The results of this study agree with (Ogundare, Odita, Obed, & Balogun, 2009) where the average glandular dose was (2.5) (mGy), and the study (Sulieman, et al., 2018) also recorded higher values of the mean glandular dose (3. 22) for each breast. This difference in doses between the current and previous studies may be due to the difference in the techniques used in imaging or the radiological system used and the conversion factor (g), which depends on the type of devices used, and the anatomical structure of the breast has affected this difference.

The average age of the patient in this study (50.8± 11.55) (29-75) years as shown in Table (4.1), the average age (50 years), the age group (41-50) represented 36.70% Of the samples, in this study, the age group (41-75 years) represents 78.3% of the total samples, while the age group (20-40) represents 21.7% and they are young people, as shown in Figure (4.1). A large percentage of these samples had normal results upon examination, and the mammogram did not detect any suspicious changes or lesions, which makes the patient at risk of cancer induced by radiation imaging without need.

Figure (4.3) indicates the form of the relationship between the average glandular dose and the thickness of the compressed breast, while Figure (4.4) shows the independence of the dose that the patient receives from the patient's age. This indicates that the patient's age as a number has no effect on the dose, but the anatomical structure and the tissues that make up the breast in this Age is influencing. There is a strong positive correlation between mean glandular dose (MGD) and tube current (mAs) used and it is significant at the level of significance (b <0.01) or less (0.001). There is a positive correlation between (breast thickness) and (mAs). The applied voltages showed a weak correlation with (mAs), as shown in Table (4.4). The mammogram radiation resulting from the examination is a major source for the development of new cancers for the patient, regardless of the dose. There is an expected risk. Some tests show negative results due to the presence of cancerous lesions or masses. Therefore, a restrictive criterion of justification is recommended for the purpose of avoiding the patient from doses he is in need of exposure to.

5.2 Conclusion:

There is a statistically significant relationship at the level of significance (0.05) or less between (MGD) and parameters of exposure (KVP,mAs) and breast thickness (mm). The doses obtained from this procedure are low compared to previous studies and were at the same level and comparable in other studies. The dose delivered to the patient depends on the technique used in imaging, the type of device used, and the protocol adopted in the radiology department. A review of the examination protocols and the accurate justification of doses is an important aspect in reducing unnecessary exposure to radiation for patients.

5:3 Recommendations:

- The radiation doses estimated in this study by the x-ray generators in the department in which the examination was carried out did not exceed the international agreed values, so it is acceptable for the safety of patients.

-The radiation dose a patient receives is affected by the tube current used during the examination.

-The dose is significantly affected by the thickness of the breast, so samples of thicknesses of a certain rang can be taken to study the relationship and explain it clearly.

- In this study, there were two values of the kVp used, and they were not sufficient to clearly study the relationship between them and the radiation dose. Therefore, several values of the kVp can be tested to explain this effect.

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