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DEPARTMENT OF RADIOLOGY

EVALUATION OF IMAGE QUALITY AND MEAN GLANDULAR DOSE FOR PATIENTS UNDERGOING MAMMOGRAPHY X-RAY EXAMINATION AT TIKUR ANBESSA SPECIALIZED HOSPITAL, ETHIOPIA

DISSERTATION FOR COMPLETION OF RADIOLOGY RESIDENCY TRAINING

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Declaration

*I, **Dr. Abdulmejid Suleyman Mume** with the registration number of **GSR/7706/14**; do hereby declare that this thesis entitled* **'Evaluation of image quality and mean glandular dose for patients undergoing mammography x-ray examination at Tikur Anbessa Specialized Hospital, Ethiopia'** *is my original work and that it has not been submitted partially; or in full, by any other person for an award of degree in any other university/institution.*

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This thesis has been submitted for examination with my approval.

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Approval

The undersigned certify that they have read and hereby recommended to Addis Ababa University to accept the thesis submitted by ***Dr. Abdulmejid Suleyman Mume*** *entitled* ***'Evaluation of image quality and mean glandular dose for patients undergoing mammography x-ray examination at Tikur Anbessa Specialized Hospital, Ethiopia'*** *for partial fulfillment of the requirements for the award of certificate in Clinical Radiology.*

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Abbreviations and Acronyms

MGDc	calculated Mean Glandular Dose
MGDm	Mean Glandular Dose displayed by machine
QA	Quality Assurance
QC	Quality Control
DM	Digital Mammography
SFM	Screen Film Mammography
ESAK	Quantity Entrance Surface Air Kerma
KERMA	Kinetic energy released to matter
kVp	Peak Kilo Voltage ,unit of tube potential
HVL	Half Value Layer
TASH	Tikur Anbessa Specialized Hospital
mAs	Miliampere Second ,unit of tube
PMMA	Polymethyl Methacrylate
CC	Craniocaudal
MLO	Mediolateral Oblique
ALARA	As Low As Reasonably Achievable
TASH	Tikur Anbessa Specialized Hospital
IQR	Interquartile range
ACR	American college of radiology

Table of Contents

Abstract

Background: Breast cancer is the most commonly diagnosed cancer and the most common cause of cancer-related death in women. Mammography is the imaging modality of choice for early breast cancer detection at curable stage. But acquiring good quality mammograms are challenging to obtain because of poor contrast between normal and pathologic breast tissues. Furthermore, inappropriate mammographic technique can lead to unnecessary high radiation dose to the breast tissue and poor image quality resulting in incorrect diagnoses and high number of unnecessary biopsies. The mammography unit at Addis Ababa University, Tikur Anbessa Specialized Hospital, may produce poor-quality mammography images with the highest breast doses. Hence, the objective of this study was to assess the image quality and breast doses in all mammography practices at Tikur Anbessa Specialized Hospital.

Methods:The sample size was determined based on the International Commission for Radiation Protection (ICRP) recommendations for conducting such studies. According to the ICRP, patient dose surveys should include at least 50 patients. Technical parameters for each patient, such as peak kilovoltage, compressed breast thickness, and miliampereseconds for each patient was recorded by data collectors. Remaining data on phantom image quality was gathered using various exposure modes and tube potentials. Furthermore, a variety of criteria are used to assess the clinical image quality of each mammogram, including the ability to clearly see the nipple and pectoralis muscle among others. The collected and cleaned data were entered into SPSS (version 27) and analyzed. P-value < 0.05 was considered statistically significant.

Results: The average calculated mean glandular dose for the craniocaudal (CC) view was 1.153 mGy ranging between 0.436-1.929 mGy. The average calculated mean glandular dose for the mediolateral oblique (MLO) view was 1.217 mGy ranging between 0.457- 2.210 mGy. The average clinical image quality for CC and MLO was 78 and 80 % respectively. The phantom image quality turned out to be 4 fibers,3 simulated specks of calcifications, and 3 masses.

Conclusion: The study concluded that the mammography unit at Tikur Anbesssa Specialized Hospital has kept the radiation exposure below the level recommended by the American College of Radiology (<3 mGy) while achieving good image quality. Additionally, it validated the close comparison between computed mean glandular dose (MGD) and machine recorded MGD, indicating that machine recorded MGD can be used to follow radiation exposure, saving time and resources.

Keywords:

Mammography; Compressed breast thickness; Mean glandular dose; peak kilovoltage; miliampereseconds Craniocaudal; Mediolateral oblique.

1. Introduction

1.1 Back ground

Breast cancer is the most prevalent type of cancer among women worldwide, including in Ethiopia.In 2020, it accounted for 25.8% of all cancer cases among women and 12.5% of all cancers in the general population. It ranks as the world's fifth most common cause of cancer-related mortality[1]. According to the International Agency for Research on Cancer (IARC), there were 685,000 breast cancer related deaths and about 2.26 million new cases globally in 2020[1]. In 2018, breast cancer was the first leading cancer type which accounts for 22.6% and 17.0% of the morbidity and mortality of the cancer burden in Ethiopia [1] . Researchers around the globe have found out that early diagnosis of breast cancer can prevent many deaths from the disease. Mammography is an imaging modality for early breast cancer detection typically through detection of characteristic masses and micro-calcifications[2].

Mammography accomplishes this by producing images of the breast's internal structures using low-dose X-rays. [3] .The tissue weighting factor of the breast glandular tissue is 0.12, indicating that it is radiation sensitive. [3]. The mean glandular dose (MGD) is the quantity that best describes the radiation received by breast glandular tissue during mammography procedures [3]. The MGD, which is the average dose absorbed by the central portion of the breast, is the most effective way to demonstrate radiation risk, according to Gholamkar et al. A number of variables, including the target or filter combination, breast thickness, X-ray tube current, exposure duration, and peak voltage employed during radiation exposure, influence the MGD calculation[3]. The goal of screening mammography is to identify breast cancer early by encouraging healthy women above 40 years of age to have their breasts examined by low energy x-ray at regular interval [4]. Mammographic examinations can also be performed for diagnostic purpose in women who have a breast lump.

Numerous researchers have objectively demonstrated the advantages of screening mammography.Screening mammography has been demonstrated to lower breast cancer mortality by up to 25% based on randomized controlled trials[4]. However, the effectiveness of mammography in diagnosing breast cancer at its earliest stages is also associated with a slight but non negligible risk of radiation-induced breast cancer to fibro glandular tissue especially if it is not monitored [4]. Therefore, it is essential to regularly monitor the mean glandular dose of the breast during mammography to prevent the occurrence of too high doses. Consequently, breast dose evaluations have been incorporated into numerous quality assurance (QA) procedures to regulate the diagnostic appropriateness of mammography imaging methods.

[4]. Precise diagnostic information with an appropriate dosage to the breast is the aim of any mammography examination. Therefore mammographic studies have to be justified in terms of radiation safety, which necessitates frequent dose monitoring. [5]. A dose level for a classic x ray study of sets of patient with standard body size and widely used machines is known as a diagnostic reference level [5]. When acceptable practice is employed with regard to diagnostic and technical performance, these levels are expected to be

maintained for standard procedures [5]. According to the ICRP local DRL is described as "for a defined clinical imaging task, based on the 75th percentile value of the distribution of the appropriate DRL quantity in a reasonable number (e.g., 10–20) of X-ray rooms" [6]. Its aim for local detection of X-ray units that require additional optimization . [6]. ACR states that the mean glandular dose of a single cranio-caudal view of a 4.2-cm thick, compressed breast having of 50% glandular and 50% adipose tissue should be less than 3.0 mGy, although it is much below this level in real practice [5].

Mammography is used in breast cancer screening to identify cancer in its early stages because it can minute alterations in tissue composition such as microcalcifications. This is challenging task since connective tissues, glandular tissues, skin and fat must be visualized but all have very similar attenuation coefficient and thus produce little subject contrast. Furthermore, it is also necessary to image micro calcifications as small as 100 micro diameters. Insufficient soft tissue contrast between normal and pathological breast tissue makes it difficult to acquire high-quality mammograms, making it the most challenging radiographic studies. Mammograms of bad quality can only result in wrong diagnoses and further unnecessary biopsies. Therefore it is necessary to utilize image quality phantoms and image it at regular interval to preserve this high image quality and verify that it has not deteriorated over an extended period of time[7].

In order to compare various mammography techniques and evaluate the impact of technical parameters on absorbed dose, phantoms are usually utilized. It is believed that a 45 mm thick polymethyl methacrylate (PMMA) phantom, known as "the standard phantom," represents the typical breast in terms of the ionizing radiation attenuation and scatter properties[8]. The dose delivered to the breast can be estimated by measurements on patients or in most cases by using a phantom.

The dose imparted to the breast is influenced by the x-ray spectrum, KVp value as well as breast thickness and composition[9] . Two views of each breast are incorporated in basic mammography imaging: the mediolateral oblique (MLO) and craniocaudal (CC) views Both basic mammography views may expose the patient to excess.

Furthermore, the likelihood that the tumor would go undetected can be increased by low imaging quality[10] .This fact has led to the development of quality assurance protocols in an attempt to standardize the imaging techniques and other procedures involved . The image quality must enable the detection of macrocalcifications and tiny masses with minimal contrast difference to the surrounding fibroglandular tissue. Additionally, the radiation dose given to the breast must not be greater than what is required for this purpose. Ultimately, it is necessary to optimize the relationship between dose and image quality.

Mammography uses low energies spanning between 25 -35 KVp. Thus, the radiation dose decreases rapidly as it penetrates deeper into breast tissue. These necessities the determination of a quantity that represent the real radiation risk to the fibro glandular tissue from ionizing radiation. In some straightforward comparison scenario, the entrance surface dose might be employed as a measure of radiation exposure.However, it is shown to be a poor predictor of the risk of cancer.

The mean dose to glandular tissue is currently believed to be the most useful indicator of carcinogenesis risk [11]. Thus, the suggested quantity to be measured as indicator oncogenic risk to the breast glandular tissue is the mean glandular dose (MGD). MGD is a quantity that represents the mean dose delivered to the breast. In mammography, phantom-based quality control procedures can be used to assess mean glandular dose (MGD) and mammogram quality. Although mean glandular dose cannot be determined directly, it can be computed based on certain parameters and assumptions. The beam quality or half-value layer (HVL), the compressed breast thickness (CBT), the breast tissue compositions, and ESAK (radiation dose measured at the breast's entrance surface) are used to calculate MGD. To determine the MGD, a precise measurement of HVL is necessary. HVL can also be used to track the X-ray tube performance over time [12]. MGD is an important quantity used to verify overall performance of the mammography system in addition to being the best indicator of carcinogenic risk to fibro glandular tissue (11). Utilizing an appropriate mammography phantom is an excellent technique to follow how well the imaging system is working as a whole (11). Features that mimic masses, calcifications, and fibers should be incorporated in an acceptable phantom. (11). It is well known that implementing quality assurance (QA) procedures for diagnostic radiology set up improves imaging equipment performance (11). The purpose of this study was to evaluate the performance status of mammography equipment with respect to radiation dose and image quality. The results of our study can be used to initiate the institution to take the necessary steps to correct unfavorable outcome in terms of image quality and mean glandular dose case part of of routine QA procedure.

1.2 Objectives

General Objective:

- The general objective of this research is to evaluate mean glandular dose (MGD) and image quality of mammography examination, thereby to promote good imaging parameters and control medical radiation exposure to a level commensurate with the clinical purpose of medical imaging task.

Specific objectives:

- To drive the relation between the relatively easily measurable quantity entrance surface air kerma (ESAK), peak kilo voltage, HVL, MGD and image quality.
- To compare the MGD displayed by DM system to directly calculated MGD.
- To evaluate relation of MGD with demographic factors like age of patient
- To examine the methods currently employed in Ethiopia for mammography examinations,
- To find optimal imaging parameters that increases image quality and minimize mean glandular dose.
- To compare competing imaging techniques as a part of quality assurance during assessment of the performance of mammographic equipment.

1.3. Research Questions

- Are the mean glandular dose values during mammography imaging at TASH within the international mean glandular dose reference level?
- Does digital mammography system have any advantages over the old screen film system with regard to MGD?
- What are the factors affecting MGD?
- Are there any differences between the CC and MLO views in terms of MGD?
- Is the image quality adequate?

1.4. Significance of the study

It is a known fact that both diagnostic and screening mammograms are an efficient means to lower the death rate from breast cancer. The issue of radiation risk from the mammography itself and image quality has also been brought up by the increased use of mammography worldwide.Most of national mammography quality assurance programs include assessments of the radiation doses to the breast and the quality of mammogram [13] . A systematic quality control program must be implemented in each country where mammography procedures are performed in order to track the functionality of the equipment and to give documentation in the event of equipment failure. The QA process needs to be performed on regular basis. It demands meticulous and consistent documentation as well as comparison with baseline tests acquired during acceptance. When difficulties happen regarding mammography system , the proper corrective action must be done, followed by testing to ensure the issue has been fixed. In Ethiopia where there are no sufficient medical physicists, neither quality control nor image quality assessment is performed regularly. This implies that the existing mammography unit in the country may not have sufficient image quality with high dose radiation exposure.

This enables a more direct assessment of breast imaging situation at TASH in Addis Ababa, Ethiopia. The expected benefit can be compared with this risk and procedures may eventually be changed in view of the outcome of this analysis. In addition, the relation between the relatively easily measurable quantity entrance surface air kerma (ESAK), peak kilo voltage, tube current, compressed breast thickness and dependent variable (MGD and image quality)will be derived, facilitating the continuous evaluation and follow-up of image quality with mammography procedures at TASH in Addis Ababa, Ethiopia. The MGD and image quality must be within American college of Radiology standards for the programs to be effective in terms of positive contribution to the public health.

2. Literature review

There is a slight chance of radiation-induced cancer to the breast's fibro glandular tissues when mammograms are used to detect breast cancer in its early stage [4]. Mammograms must show a high contrast to detect breast cancer at its earliest stage , but this is difficult to achieve because the components of the breast tissue have very close radiation attenuation coefficients. [14]. The spatial resolution must also be able to display the macrocalcifications along with their shape, number, and other characteristics. However the image quality should be monitored in line with radiation dose. This tradeoff between dose and image quality is especially important in screening mammography where regular imaging is carried out to avoid excess radiation dose to the community. Mean glandular dose (MGD) is the most reliable measure of absorbed dose to the breast glandular tissue [4]. Conversion factors determined by Monte-Carlo simulations are utilized to calculate MGD[4]. Conversion factors dependent on breast thickness, glandularity, x-ray spectra, and beam quality [4] . The digital systems displays organ dose (MGD) result which serves as a digital indicator of the breast dose [4]. However, before this machine-determined MGD is utilized for dose audits or as a substitute method to create diagnostic reference levels, it must be verified against existing MGD calculation techniques. Borg et al. investigated two mammography machines, the General Electric (GE) Essential and the Hologic Selenia, to compare the dosage computed for phantom using the Monte-Carlo estimating techniques and the machined displayed organ dose. [4].They discovered that, for small to medium phantom thicknesses, the machine-calculated MGD compares well with the Monte-Carlo calculations.[4].One of our study objective is also to compare the MGD displayed by DM system to directly calculated MGD . Among the physical techniques used to assess image quality are contrast measurement, noise and spatial resolution [14] .

Image quality indicators such as visibility of microcalcifications, fibers, and masses were assessed utilizing the ACR phantom. Dellie, S., et al. conducted a cross-sectional study in Addis Ababa, Ethiopia, using 755 mammograms. The results showed that the third quartile of MGD for all government and private mammography units was 2.37 mGy and 1.73 mGy, respectively. [5]. This research was done based on screen film mammogram while our study is based on digital mammography. Breast doses from digital mammography (DM) are 22% lower per view than those from screen film mammography (SFM), according to recently released study from the American College of Radiology Imaging Network–The Digital Mammographic Imaging Screening Trial (ACRIN DMIST) [15].We want to compare if there is significant reduction in MGD between DM which is currently in use compared to previous study which was based on SFM . The image noise level must be low enough to for proper visualization of the breast structures [14]. The images saved by the Digital Imaging and Communications in Medicine protocol (DICOM) was as the source of the data. Exam date, patient age, examination view, target/filter combination (T/F), kVp, and mAs, thickness of the compressed breast,entrance surface air kerma , and mean glandular dose recorded by the equipment were collected as part of database[4]. Furthermore our study also evaluates the image quality of mammography procedure. In addition we will assess the relations between the MGD and image quality with aim of optimizing their relationship according to as low as reasonably achievable (ALARA) radiation dose principle. Few studies have been published regarding the radiation exposure and risks associated with breast imaging from screening mammography and diagnostic mammography from Ethiopia. This project aims to evaluate the radiation doses and image quality of mammography program at Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia and compare the results with national and international values. This would ensure that the protocols used are within national and international standards.

3. Methods and materials

Study Design: A descriptive cross-sectional study design was used to study the mammographic radiation exposure and image quality in patients undergoing mammography at TASH Addis Ababa from December 2024 to July 2025 GC.

Source Population: - All patients who undergo mammography examination at TASH

Study population: - All patients who undergo mammography examinations during the study period.

Sample size and sampling method : The sample size was determined based on international commission for radiation protection (ICRP) [16] recommendations to conduct such study. According to the ICRP, patient dose surveys should include at least 50 patients with standard breast sizes. Convenience sampling method was used. All patients coming sent for screening and diagnostic mammography to TASH during study period were included. Patients with abnormal mammographic finding were excluded.

The independent variables in our study included age of the patient; view of examination; the technical parameters of exposure (target/filter combination (T/F), kVp, and mAs; the thickness of the compressed breast; the compressive force, half value layer and tube output.

The dependent variables includes calculated and machine determined mean glandular dose(MGD) and entrance surface air kerma(ESAK) .

Methods of Data Collection and materials

Materials needed are Fujifilm amulet digital mammography machine, dosimeter, ACR mammography phantom and aluminum bars to determine half value layer (figure 1and 2) .In this study the, Gammex Mammographic Accreditation Phantom, 4.0cm polymethylmethacrylate (PMMA) was used (equivalent to 50% glandular tissue and 50% adipose tissue, 4.2 cm thick compressed breast) .These phantoms have fibers, specks and masses with decreasing diameters and thicknesses. When scoring the image of one of the ACR-approved accreditation phantoms, each object type is scored separately. Always we will count the number of visible objects from the largest object of a given type (i.e., fibber, speck group, or mass) downward until a score of 0 or 0.5 is reached, then we will stop counting for that object type. To pass the MQSA image quality standards – at least four fibbers, – three calcification groups, – and three masses must be clearly visible (with no obvious artifacts) at an average glandular dose of less than 3 mGy [16].

The rest of data were obtained directly from each image stored in the Digital Imaging and Communications in Medicine protocol (DICOM). The data was obtained directly from each image stored in the Digital Imaging and Communications in Medicine protocol (DICOM). The database is composed of the exam date; age of the patient; view of examination; the technical parameters of exposure (target/filter combination (T/F), kVp, and mAs); the thickness of the compressed breast; the compressive force; the entrance surface air kerma exposure; and the mean glandular dose as registered by the equipment. In this research the following quality control (QC) tests were also be performed:-reproducibility and accuracy of kVp, tube output, HVL, compression force, average beast thickness and mean glandular dose.So as to account for the exposure reduction and beam hardening that may occur due to compression plate , the detector was placed on the breast support table halfway along the direction perpendicular to the anode–cathode axis at 4.5 cm from the image receptor holder and 6 cm from the edge of the chest wall..

The formula below was used to determine the calculated MGD of patients undergoing mammography X-ray examinations.

$$\mathbf{MGD = ESAK * g * c * s}$$

ESAK is the air kerma entrance surface at the upper surface of the breast or phantom

The values determined by Dance et al. [17] were used to construct the factor g, which represents a glandularity of 50%[17].

The c-factor compensates for any variation in breast composition from 50% glandularity.

The factor s accounts for any disparity produced by the choice of the X-ray spectrum.

MGD will be calculated for each exposure by multiplying the tube loading and the measured tube output for the relevant tube voltage with correction for the distance to the patient's skin surface.

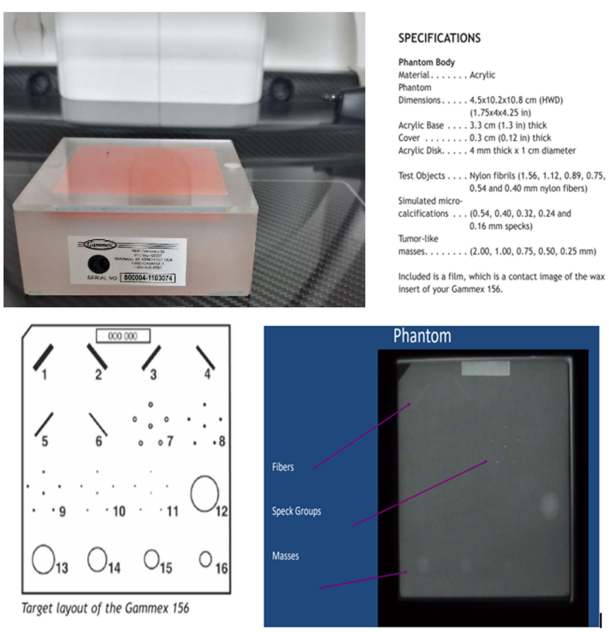

Figure 1 Mammographic accreditation phantom and its sample mammographic image

Figure 2 Phantom being imaged by Fujifilm amulet system

Images were viewed on the same viewer used clinically. Phantom images were read under optimal viewing conditions and the results were recorded. Images were masked to eliminate extraneous light. We used a magnifying glass of 2X or higher for scoring specks groups as well as any other appropriate test objects. When Gammex phantom is used to create an image, the mammographic system passed the test if we detect a minimum of 4 fibers ,3 groups of simulated micro-calcifications and 3 masses.

Methods of Data Analysis

The prepared data collection forms were distributed to the technologists/radiographers working at mammography unit and filled. After data completeness and consistency is checked the mean, median, minimum, maximum of calculated ESAK, MGDs, tube potential (kVp), tube current (mAs) compressed breast thickness were calculated using (SPSS 27). The number of masses, calcification groups, and fibers were also analyzed based on exposure mode. Finally the result was compared with a similar study. The correlations between independent variables and calculated MGD were also evaluated with Pearson's correlation coefficient. A linear regression analysis was used to determine the effect of the independent variables on calculated MGD values. The relationship between independent variables, ESAK and MGD will be investigated using bivariate analysis. A significance level of $P < 0.05$ was chosen.

4. Ethical considerations

Before the commencement of the study ethical clearance was obtained from Institutional Review Board (IRB) of College of Health Science, Addis Ababa University. Then permission letters from hospital was processed before starting data collection. During and after data collection confidentiality of all records was guaranteed and no information by which the participants can be identified was released or published. Moreover, verbal consent was taken from the study participants to take measurements, Entrance Surface Air Kerma, and image quality.

5. Results

A total of 200 mammographic film was studied from 80 patients.

Among the findings are demographics, the distribution of tube voltage (kVp), tube current (mAs), compression force, compressed breast thickness (CBT), calculated and machine displayed MGD. Phantom and clinical image quality was also included. Finally, comparisons and relationships between the mentioned variables were summarized and put in table form.

Table 1- Descriptive analysis of dependent and independent variables for MLO view

Variable	Min	Mean	Mean	Median	IQR
Age	40	49	64	46	40.25 - 56.75
MAS	20	60	93	59	50 - 71.75
KVP	26	28	30	28	27 - 29
TOP	0.016	0.049	0.056	0.048	0.440 - 0.519
CBT (mm)	20	40	67	41	31 - 50.75
ESAK (mGy)	0.846	3.412	6.108	3.267	2.467 - 4.369
MGDm(mGy)	0.310	1.049	1.860	0.98	0.835 - 1.27
MGDc(mGy)	0.457	1.217	2.211	1.190	1.024-1.422
HVL (mm Al)	0.544	0.565	0.578	0.567	0.555 - 0.570

Table 2- Descriptive analysis of dependent and independent variables for CC view

Variable	Min	Mean	Mean	Median	IQR
Age	40	49	64	46	40.25 - 56.75
MAS	19	55	85	54	46-67.5
KVP	26	27.87	30	28	27-29
TOP	0.016	0.048	0.056	0.048	0.440-0.519
CBT (mm)	18	35	57	37	27.25-42
ESAK (mGy)	0.804	2.997	5.523	2.88	2.235-3.852
MGDm(mGy)	0.360	0.984	1.660	0.92	0.812-1.167
MGDc(mGy)	0.436	1.154	1.939	1.108	0.988-1.330
HVL (mm Al)	0.544	0.563	0.578	0.567	0.555-0.570

Table 3- Bivariate Correlation Coefficients (Pearson r) and linear regression of variables with MGDc.

Variables	MGDc (r)	MGDc (β)	p-value
Age	-0.45	- 0.02	< 0.001
kVp	0.81	0.22	< 0.001
mAs	0.92	0.02	< 0.001
CBT	0.56	0.01	< 0.001
MGDm	0.976	1.04	< 0.001
ESAK	0.89	0.22	< 0.001
TOP	0.81	56.2	< 0.001
HVL	0.77	0.22	< 0.001

❖ **Age of patients:**

The median age of patient was 46 years with interquartile range between 40.25 and 56.75 year. In our study the lowest age was 40 and the highest being 64 years (Table 1). Bivariate analysis of age and MGDc demonstrated weak negative correlation with r of -0.45 (Table 3). Linear regression scatter plot showed statistically significant but weak negative association between age and MGDc with βof - 0.02 (figure 3).

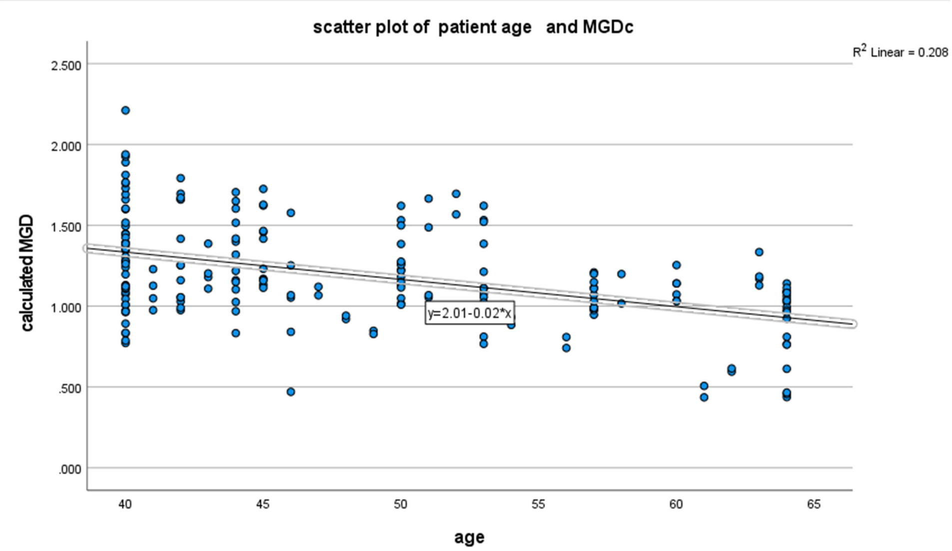

Figure 3- A linear regression scatter plot illustrating the relationship between patient age and MGD

❖ ***Compressed breast thickness (CBT)-***

The CBT of the patients ranged from 20 to 67 cm for MLO and 18 to 57 cm for CC View (Table 1). The mean CBTs were 40 cm for MLO and 35 for CC view. Bivariate analysis of CBT and MGD c demonstrated moderate positive correlation with r of 0.56 (Table 3). Linear regression scatter plot showed statistically significant moderate positive association between CBT and MGDc with βof 0.01 (figure 4) .

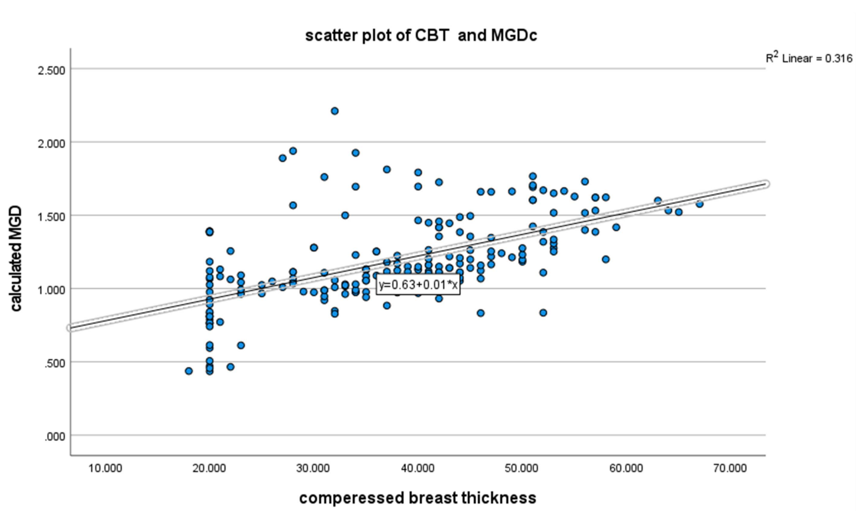

Figure 4- A linear regression scatter plot illustrating the relationship between CBT and MGD

- **Calculated Mean glandular dose (MGDc)**

We found out that the calculated MGD ranged from 0.457 to 2.21 mGy for MLO view and 0.436 to 1.93 mGy for CC view (Table 1 and 2). The mean value was 1.217 for MLO view and 1.154 for cc view. Linear regression scatter plot demonstrated statistically significant strong positive association between MGDm and MGDc with βof 1.04 (figure 5) .

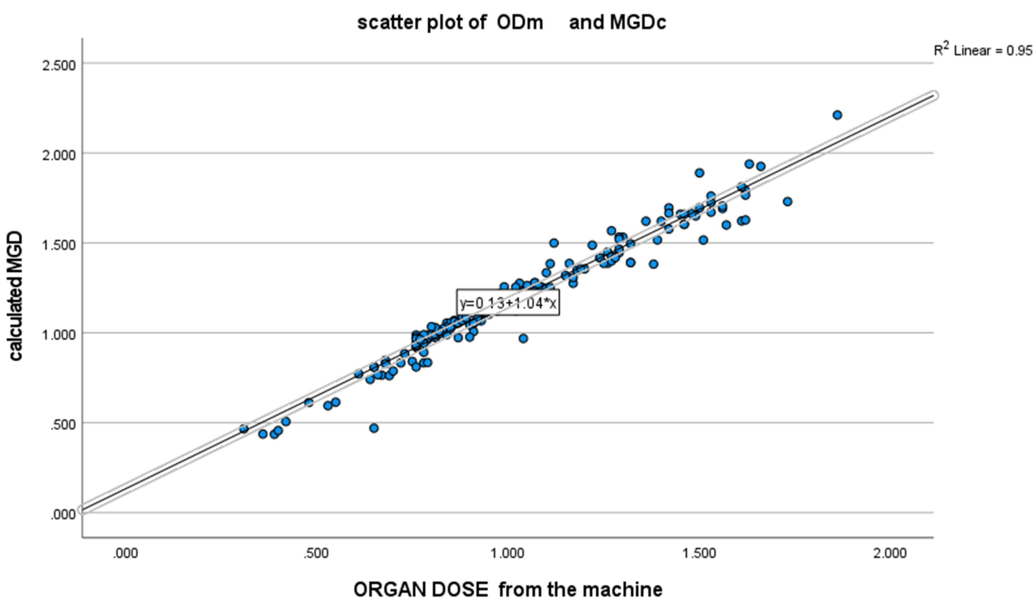

Figure 5- A linear regression scatter plot illustrating the relationship between MGD displayed by Fujifilm units and MGD determined by the Dance et al methods. (Fujifilm systems also uses Dance method for the determination of organ dose).

- **MGD displayed by the Fujifilm mammography machine (MGDm)**

We found out that , the MGD displayed by the machine ranged from 0.31 mGy to 1.86 mGy for MLO view and 0.36 to 1.66 mGy for CC view (Table 1 and 2).The mean value were 1.049 for MLO view and 0.984 for CC view (Table 3).Bivariate analysis of machine displayed and calculated MGD demonstrated strong positive correlation with r of 0.976 (Table 2) .Linear regression scatter plot demonstrated statistically significant strong positive association between calculated and displayed MGD with β of 1.04 (figure 5) .

- **Calculated Mean glandular dose per examination for combined CC and MLO view**

We found out the MGD per examination for both mammographic views ranged between 0.893 to 4.14 mGy with mean of 2.371 mGy .

❖ **Tube current in mili amperesecond(mAS)**

The tube current of the exposure ranged from 20 to 93 mAs for MLO and 19 to 85 mAs for CC View. The mean mAS were 59.6 mAS for MLO and 54.9 mAS for CC view (Table 1 and 2). Bivariate analysis of mAS and MGDc demonstrated strong positive correlation

with r of 0.92 (Table 3) .Linear regression scatter plot showed statistically significant weak positive association between MAS and MGDc with βof 0.02 (figure 6)

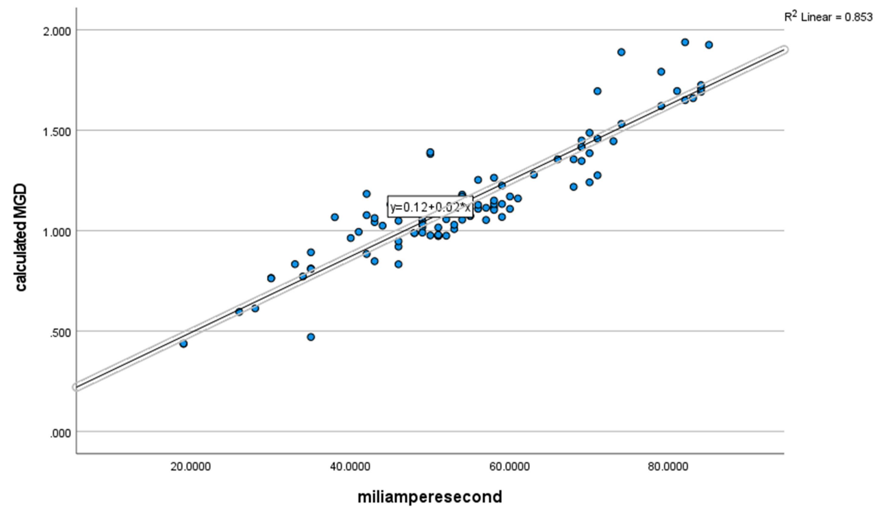

Figure 6- A linear regression scatter plot illustrating the relationship between mAs and MGD

❖ **Tube potential (KVP)**

In Our study the most the used tube potential ranged from 26 to 30 KVP for both MLO and CC View (Table 1 and 2).he mean as well as most used kvp were 28 for both MLO and CC view . Bivariate analysis of kvp and MGDc demonstrated strong positive correlation

With r of 0.81 (Table 3). Linear regression scatter plot of KVP and MGDc showed statistically significant weak positive association (β=0.22) but stronger than MAS (Figure 7).

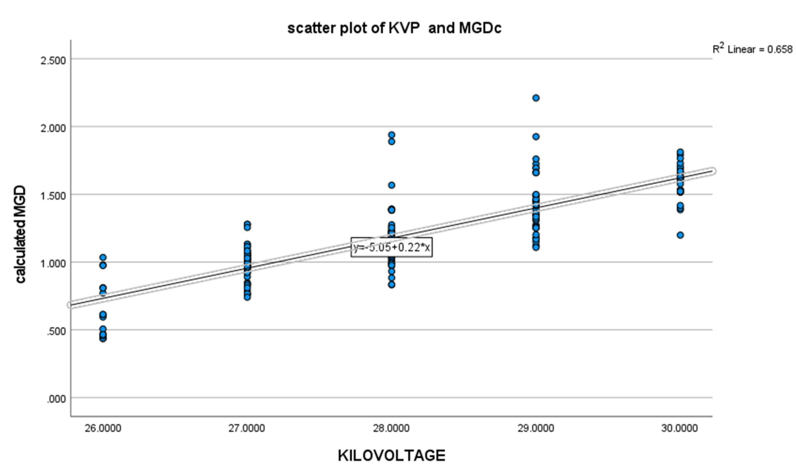

Figure 7- A linear regression scatter plot illustrating the relationship between KVp and MGD.

- **Tube output (TOP)**

The tube output of the exposure ranged from 0.04 to 0.056 R for both MLO and CC View. The mean TOP were 0.0480 for MLO and 0.0475 for CC view . Bivariate analysis of TOP and MGDc demonstrated strong positive correlation with r of 0.92 (Table 2) .Linear regression scatter plot of TOP and MGDc showed strong positive association βof 56.2 above all other variables (Table 3 and figure 6) .This can also be explained as one unit increases in tube output can increase the MGDc by a factor of 56.2 ,which is the strongest effect seen in our study.

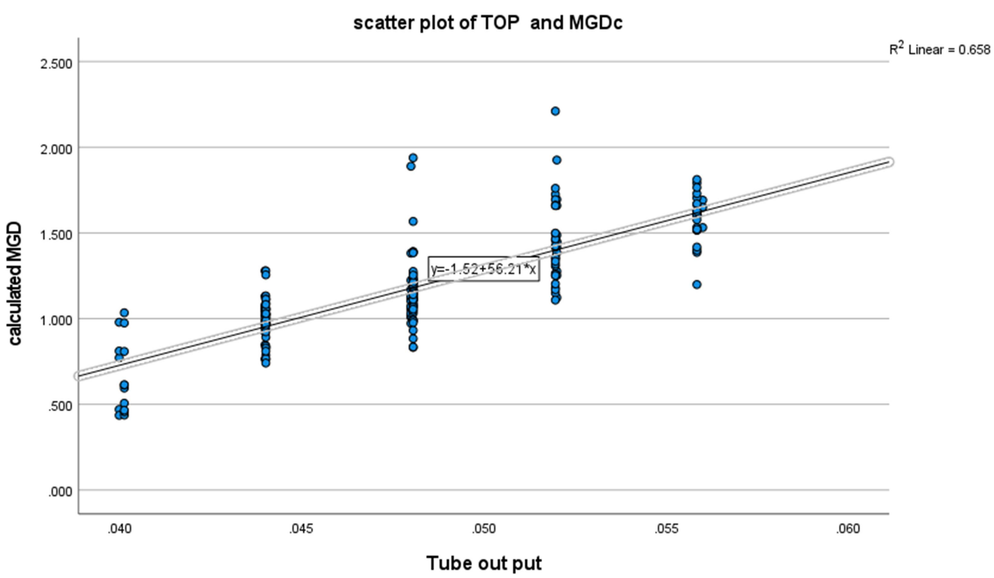

Figure 8- A linear regression scatter plot illustrating the relationship between tube output (TOP) and MGD

- **<u>Entrance surface air KERMA (kinetic energy released to matter),ESAK</u>**

The ESAK of ranged from 0.85 to 6.10 mGy for MLO and 0.80 to 5.5 mGy for CC View. The mean ESAK were 3.42 mGY for MLO and 3 mGY for CC view . Bivariate analysis of ESAK and MGDc demonstrated strong positive correlation with r of 0.89 (Table 3) .Linear regression scatter plot showed weak positive association between ESAKand MGDc with βof 0.22 (Table 3 and figure 9)

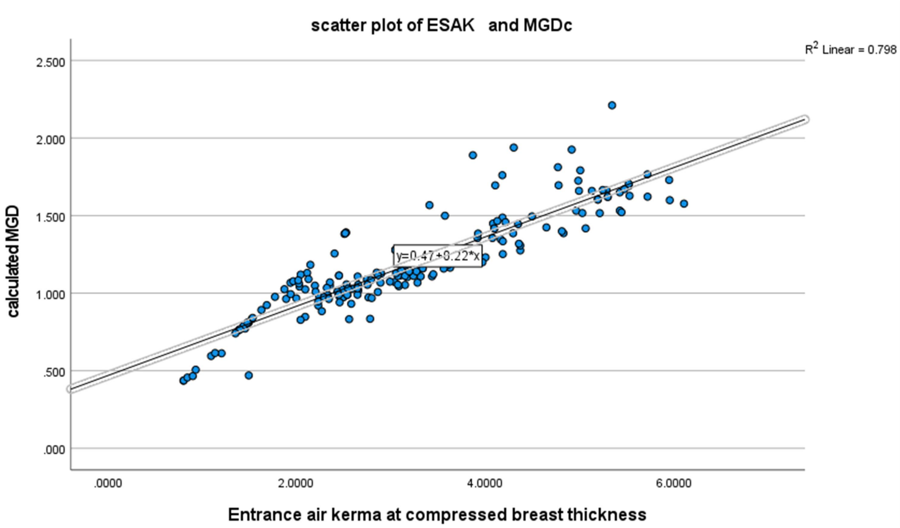

Figure 9- A linear regression scatter plot illustrating the relationship between ESAK and MGD

❖ **Clinical image**

Clinical image quality was also within adequate range (78 percent for CC and 80 % for MLO view). Bivariate analysis of clinical image quality and MGDc demonstrated weak positive correlation with r of 0.18. Linear regression scatter plot showed positive association between clinical image quality and MGDc with βof 0.81 (figure 10).

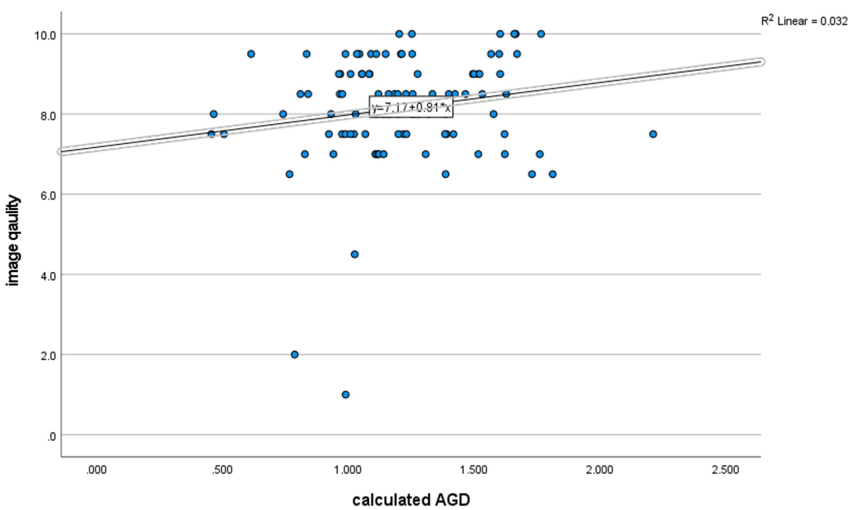

Figure 10 - A linear regression scatter plot illustrating the relationship between image quality and MGD

❖ **Phantom Image quality**

Phantom image quality and MGDm was persistently within the requirement of ACR (4 fibers, 3 simulated specks of calcification and 3 masses) despite tube potential variation except the manual exposure mode which failed to pass the quality test

Table 4- Phantom Exposure and image quality results

ACR Phantom Images	KVP	MAS	MGD in mGy	Number of fibers seen	Number of calcification seen	November of masses seen	Exposure control mode
A	24	107	0.85	4	3	3	Semiautomatic
B	26	81	0.92	4	3	3	Semiautomatic
C	28	58	0.88	4	3	3	Semiautomatic
D	30	48	0.88	4	3	3	Semiautomatic
E	32	42	0.92	4	3	3	Semiautomatic
F	29	53	0.87	4	3	3	Automatic
G	28	36	0.54	0	0	0	Manual

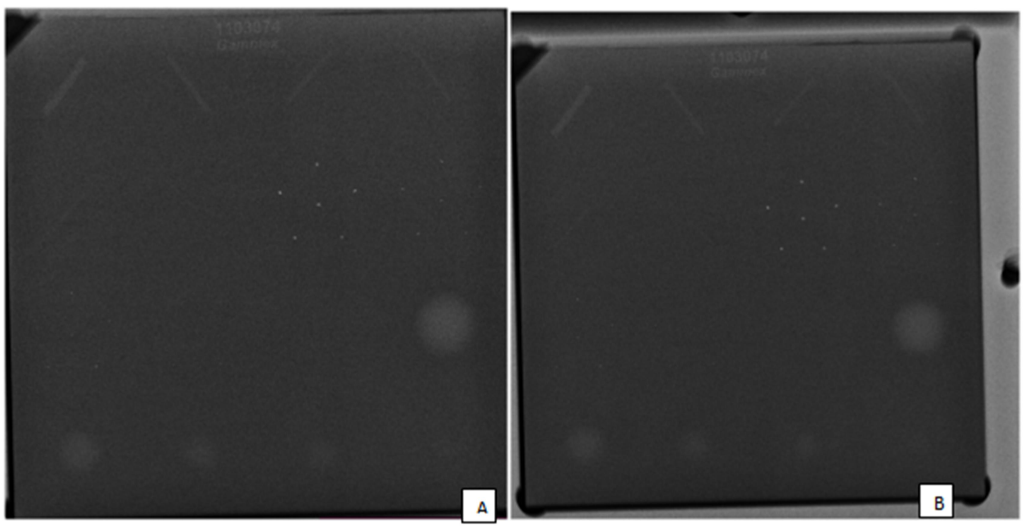

Figure 11- Phantom image A and B taken at 24KV, 107 MAS and 26 kv and 81 MAS with semiautomatic exposure

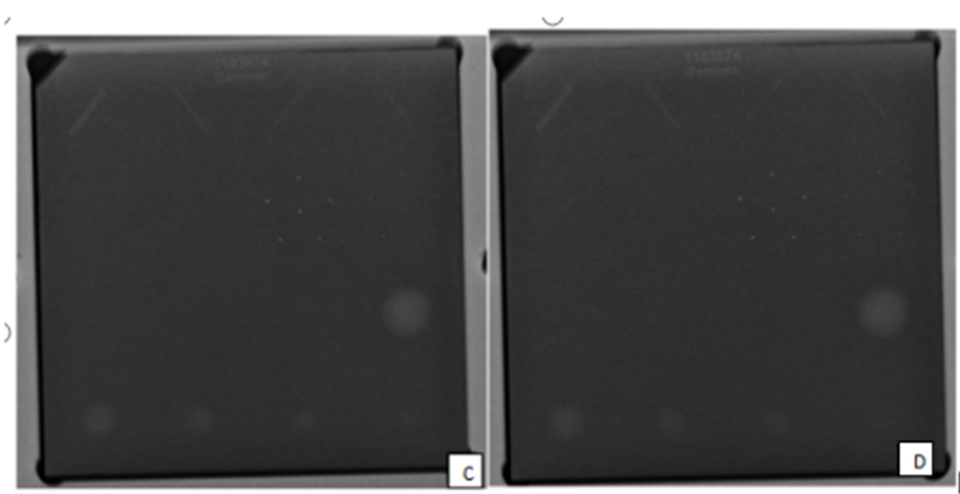

Figure 12 -Phantom image C and D taken at 28 KV ,58 MAS and 30 kv and 48 MAS with semiautomatic exposure

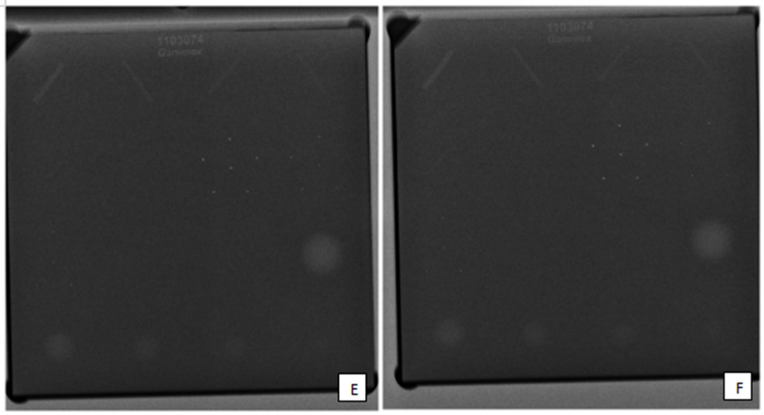

Figure 13- Phantom image E   taken at 32 KV ,42MAS   with semiautomatic mode. Phantom image F taken at 29 kv and 53 MAS with automatic mode

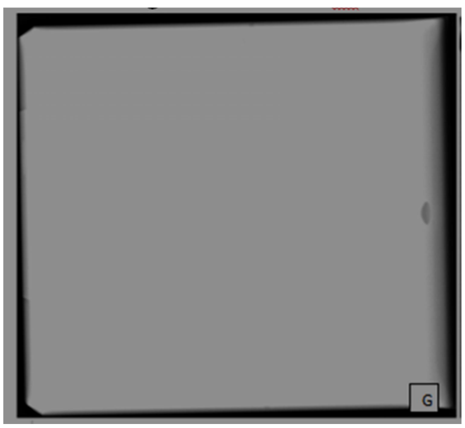

Figure 14- Phantom image G taken at 28 KV and 50 MAS with manual mode

- ❖ Comparison of CC and MLO view – Both machine displayed (MGDm) and calculated mean glandular dose (MGDc) are slightly higher on MLO view than the CC view.

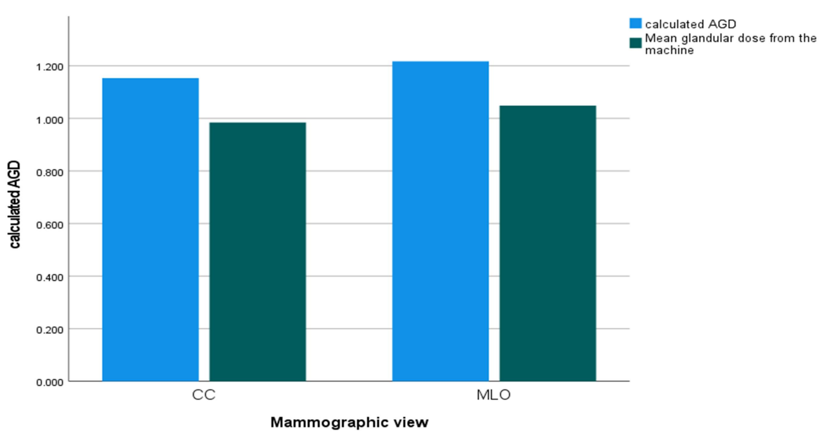

Figure 15- Comparison of CC and MLO view in terms of MGDc and MGDm .

6. Discussion

Our study demonstrated the radiation dose per view is well within the standard of ACR (<3 mGy) for both CC (1.153 mGy) and MLO view (1.217 mGy) .It also showed that the mean glandular dose from machine and calculated mean glandular dose have strong positive correlation (r =0.976, β=1.04). This suggests that machine-displayed MGD can be utilized to accurately monitor radiation exposure of breast glandular tissue without requiring the time consuming procedure of calculating MGD, saving time and money.Study by Suleiman on Mean glandular dose in digital mammography using Fijifilm amulet ,also showed an excellent correlation between MGD determined by the machine and calculated MGD similar to our study with R of 0.96[4].MGD are slightly higher on the MLO view which can be explained by the thicker compressed breast thickness as is confirmed in our case (figure 15). The weak negative association demonstrated between age and MGDc (r = -0.45) may be attributable to the lower amount of glandular tissue seen in breasts of older patients (Figure 1). But we need further study with higher sample size to assess the strength of correlation further. Among the independent variables MAS showed strongest positive correlation (r = 0.92) with MGDc followed by KVp and TOP (r = 0.81). The half value layer had also strong correlation (r = 0.77) although smaller than the above variables. The CBT showed only moderate positive correlation with MGD. This can also be because of small sample size and needs further confirmation with multicenter and larger sample size.

Linear regression showed MGDc is most affected by tube output (β=56.2) and HVL (β=25.7) .This implies that small change in TOP and HVL can exponentially increases the radiation dose to the patients .This can be explained by the fact that tube output and HVL includes the effect of multiple independent variable like MAS,KVP and CBT .The KV affects the radiation dose more than the MAS and CBT underscoring the need to monitor this factor for dose control.In our study with all projection average MGD was 1.18 mGy per view which is well within the recommendation of ACR (< 3 mGy per view).In 2016, Dellie, S.T. conducted a study on the recommended diagnostic reference levels for mammography, which is one of the related studies from Ethiopia.According to this study, the MGD per exposure (both CC and MLO view) was 6.81 mGy, which was higher than the ACR-recommended value of less than 6 mGy for both views.The average MGD per exposure in our study is 2.37 mGy, with a maximum value of 4.4 mGy. This figure is less than the value obtained by Dellie, S.T[5].The MGD reduction in our study can be explained by the fact that the previous study performed by Dellie, S.T was done on screen film mammography system while the current study is performed on digital mammography system .The digital mammography detector has linear types of response to exposure giving us higher quality image at lower dose than screen film mammography .Digital post processing with window width adjustment can also compensate for image quality derangement stemming from slight under or over exposure unlike the screen film mammography system .At this juncture we can answer our research question related to comparing the MGD for the old system of screen film mammography and newer digital mammography system .This finding further strengthen the safety of digital system for screening mammography in which normal women's above 40 years of age are repeatedly screened for early and curable stages of breast cancer . Recently reported data from the American College of Radiology Imaging Network–The Digital Mammographic Imaging Screening Trial (ACRIN DMIST)also showed breast doses from digital mammography(DM) to be 22% lower per view than those from screen film mammography (SFM) [15] .This finding of ACRIN DMIST also strengthens our finding . The reduction of MGD on digital system van be explained by the fact that digital system has linear response to exposure which maximizes the image contrast over wider range of exposure. Digital post processing with window width adjustment can also compensate for image quality derangement stemming from slight under or over exposure unlike the screen film mammography system.

The mean of machine calculated MGD exceeded machine displayed organ dose by 0.17 mgGy (14 %) which is statistically significant amount of difference but very small to be significant in relation to the limit put by ACR of less than 3 mGy (5.6 %) .A study by Skrzyński, W. et al in Poland found out that the maximum difference between the displayed and calculated doses to be 0.41 mGy which is slightly higher than what we found out in our case yet both are too small to be significant relative to a 3 mGy values limit set by ACR[18]. Phantom image quality and MGDm (Table 4 and Figure 11 - 14) was persistently within the requirement of ACR (4 fibers, 3 simulated specks of calcification ,3 masses and maximum phantom MGDm of 0.92 mGy) despite tube potential variation. This finding can be explained by the semiautomatic exposure mode which compensates for image quality and MGD by automatically changing the tube current (mAs). The image obtained by manual exposure failed to pass the ACR image quality test. This finding clearly shows the superiority of automatic exposure overa manual exposure mode. Clinical image quality was also within adequate range (78 percent for CC and 80 % for MLO view). Generally, the clinical image quality results are similar to those of the Coordinated Research Project on Optimization of Protection in Mammography, which was conducted in eastern European countries using identical criteria. The results were 82% for CC and 78% for MLO view (Table 6 and 7) [16].The lower image quality in CC image quality can be can be explained by lower visualization of pectoralis muscle on this CC view than MLO view .We understand from this extensive study at Tikur Anbessa specialized Hospital that the digital mammography system is working well within the limit of ACR standard .It confirmed that MGD from machines correlate well with Calculated MGD.This is significant finding as it simplifies the quality control process by easily monitoring the doses from machine .This will save resource and human power needed to for quality assurance program .In addition it reassures patients undergoing the mammography procedure from fear of acquiring different types of radiation induced malignancies . Over all our study findings concludes that digital mammography system better suits with radiologic imaging basic tenet of as low as reasonably achievable (ALARA) radiation doses principle by optimizing image quality as well as radiation dose.

7. Conclusion

The results showed that the mammography unit at TASH, Addis Ababa university is working according ACR standards. The average calculated MGD for woman referred to this unit was clearly below the dose limit recommended by ACR (<3 mGy). The phantom and clinical image quality was also adequate. We also verified MGD from the machine can be sufficient for dose audit without the need to calculate MGD. Over all our study concludes that digital mammography system better suits with radiologic imaging basic tenet of ALARA principle as it is optimized both image quality and radiation dose.

8. Limitation of the study future recommendation

The MGD from machine and calculated MGD equivalency should also be checked on other DM system like GE and Philips system before being used as sole dose audit parameter. Further study with even more sample size will strengthen the relationship of MGDc and independent variables. Further study of clinical image quality with more objective image quality parameter and image evaluation by multiple radiologists will demonstrative its real association with MG. Future multicenter study will allow establishment of local diagnostic reference level .

9. Dissemination

Our finding will be submitted to Addis Ababa university radiology department and published on local and international journals.

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11. Appendices

Data collection tools

Table 5- Exposure factor and machine displayed MGD data collection form

N Patient	Patient ID	Date	Age	View	Target /Fi	kV	mAs	Compressed Breast Thickness (mm)	Compression Force (N)	Mean glandular dose (D_G) (mGy)
1				RML						
				RCC						
				LMLO						
				LCC						
2				RML						
				RCC						
				LMLO						
				LCC						

Table 6- Clinical image quality for CC view data collection form

Clinical image quality criteria for CC (craniocaudal) projection

IQ criteria	Yes =1	Doubtful =0.5	No =0
Visually sharp reproduction of **pectoral muscle at image margin**			
Visually sharp reproduction of retroglandular fat tissue			
Visually sharp reproduction of **medial breast tissue**			
Visually sharp reproduction of **lateral glandular tissue**			
No skin folds seen			
Visualization of **skin outline with bright light** (but barely without it)			
Reproduction of **vascular structures seen through most dense parenchyma**			
Visually sharp reproduction of **all vessels and fibrous strands and pectoral muscle margin (absence of movement)**			
Visually sharp reproduction **Of skin structure (rosettes from pores) along the pectoralis muscle**			

Table 7- Clinical image quality for MLO view data collection form

Clinical image quality criteria for MLO (midiolateral oblique) projection

Criteria	Yes =1	Doubtful =0.5	No =0
Pectoral muscle at **correct angle**			
Infra-mammary angle visualized			
Visually sharp reproduction of **cranio-lateral glandular tissue**			
Visually sharp reproduction of **retroglandular fat tissue**			
Nipple in full profile, clear of overlying breast tissue and/or indicated by marker			
No skin folds seen			
Visualization of **skin outline with bright light** (but barely without it)			
Reproduction of **vascular structures seen through mostdense parenchyma**			
Visually sharp reproduction of **all vessels and fibrous strands and pectoral muscle margin (absence of movement)**			
Visually sharp reproduction **of skin structure (rosettes from pores) along the pectoralis muscle**			