

Evaluation of The Mean Glandular Doses by Estimation and Measurement with Ionization Chamber in Mammography Examinations in Southwest Nigeria



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ABSTRACT

Mammography is the primary imaging modality utilizes low energy characteristics radiation for detection of abnormal growth in breasts; and its effectiveness in breast cancer diagnosis has been widely reported. Most manufacturers of mammography machine do rely on the dance formula for calculating the Mean Glandular Dose (MGD) values on the Digital Information for Communication (DICOM) header of mammography machines. The aim of this study was to check the reliability of the MGD values estimated using the Dance formula using an ionization chamber. Five mammography machines from five tertiary medical centres within Southwest Nigeria were considered for this research work. Direct measurement was carried out using the Ionization Chamber of the RadCal Accu-gold detector. The entrance surface dose was measured and thereafter converted to MGD using the recommendation of the American College of Radiology. The Ionization chamber recorded higher values for MGD per patients, ranging from 2.49 ± 1.32 mGy to 6.99 ± 3.88 mGy for CC and MLO views respectively. The MGD values per patient estimated by the detector ranged from 1.98 ± 0.84 mGy to 5.94 ± 2.78 mGy for CC and MLO views respectively. The MGD values measured by the Accu-Gold Ionization chamber were relatively higher when compared to the estimated MGD values from the DICOM header of the mammography machines. This may be due to the fact that some exposure factors like the compression contributed to the low dose recorded by the mammogram machine in the DICOM header. The study established the reliability of the MGD values estimated using the Dance formula.

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INTRODUCTION

The estimation of the absorbed dose to the breast during x-ray-based imaging is a long-established part of quality control procedures for breast imaging systems and is also necessary for risk estimation. Mean glandular dose (MGD) is the most appropriate dosimetric quantity to predict the risk of radiation induced carcinogenesis in mammographic practice. Determination of MGD for an individual woman is uncertain, as it depends not only on tissue composition, but also on tissue distribution within the breast. The estimated dose values on the DICOM

header of mammography have been based on the formula proposed by Dance et al. (2009) over decades to convert the dose. However, the reliability of the MGD values estimated by the detector using the Dance formula need to be checked by measuring the MGD through direct measurements. This is needed in order to ascertain dose optimization for mammography examinations. It has been reported in many studies that TLD chips and Ionization chamber are used to ascertain the reliability of the MGD values on mammography machines using the Dance formula through direct measurement. Supawitoo et al.

(2006) carried out a study where he used a 6-cc ionization chamber with an electrometer to obtain MGD from routine mammography in order to check the reliability of the MGD values measured by the mammography detector. He used the ionization chamber to measure the entrance surface dose in order to obtain the MGD from mammography examinations and thereafter converted to the MGD using the American College of Radiology Recommendation. His study established that higher MGD values were measured by the ionization chamber compared to the machine estimated values. This reliability check has however not been done for mammography machines in Southwest Nigeria, hence the need for this study.

MATERIALS AND METHODS

Radcal Accu-Gold Multi Sensor Detector

There are several devices that are used to undertake the quality assurance of X-ray machines like mammography. These devices however do not serve the multifunctional purpose of measuring the kVp, Dose, HVL etc of the X-ray machine as the Radcal Accu-Gold Multi-sensor instrument. The Radcal Accu-Gold Multi-sensor is a solid-state based instrument which incorporates a mammographic multi-sensor for measurement of dose, kV, and filtrations characteristics. It has a 10" display that provides an intuitive touch screen interface suitable for running the Accu-Gold windows application. Radcal instruments have provided the MQSA (Mammography Quality Standard Acts) compliant testing since inception.

Radcal Accu-Gold Multi Sensor Detector

The Radcal 10X6-6M Mammography Ionization Chamber is a parallel plate with 0.7mg/cm² metallized polyester window; polyacetal exterior, exposure rate dependence of $\pm 5\%$, 0.02R/min to 600R/min, energy dependence of $\pm 5\%$ 10keV to 40keV and calibration accuracy of $\pm 4\%$ using X-rays @ 30kVp and 0.50mm Al HVL. The breast entrance skin exposure was measured by using the ionization chamber placed in the X-ray field. The exposure measure was thereafter converted to the MGD according to the ACR recommendations (American College of Radiology, 1999).

Methods

Five mammography machines from five tertiary medical centres within Southwest Nigeria were considered for this research work. Direct measurement was carried out using the Ionization Chamber of the RadCal Accu-gold detector.

Quality Assurance of Mammography Machine

The Quality Assurance (QA) of the mammogram machines was carried out using the Radcal Accu-Gold Mammography Multi-sensor device. The following technical parameters were examined on the

Mammography machines in the study centers during the QA: kVp Accuracy and Reproducibility.

Machine Specification

Machine specification used to carry out mammography examination in each of the centres are shown in table 1. The table shows the manufacturers of the mammography machines and the exposure parameters.

Ethical Clearance

Ethical Clearance was not needed for this research work because patients were not used during the experimentation, rather phantoms (chest block) were used to mimic the patients.

Measurement of Entrance Surface Dose and Mean Glandular Dose

The Ionization Chamber of the Radcal Accu-Gold Solid State detector was used to measure the entrance surface dose and later converted to the MGD according to the ACR (American College of Medicine) recommendation using equation 1 proposed by Dance et al. (2009) below.

$$MGD = K \cdot g \cdot c \cdot s \quad 1$$

where K = ESD (Entrance Surface Dose) , g = ESD to MGD conversion factor on the assumption that the entire breast has a glandularity of 50%; c = conversion factor for difference in breast composition other than 50% glandularity; and s= conversion factor for different X-ray spectrum which can be due to different anode/filter combination.

The ionization chamber has two heads; the bigger head placed inside a chest block as seen in plate 1 and a smaller head which is pin hole-like. The pin-hole like head is connected to the AGMS port of the Accu-gold digitizer while the bigger head is placed inside a chest block and thereafter put in between the compression paddle and the breast stand as shown in plate 2. Then radiation is exposed to the ionization chamber, the photons travel through the beam setting up charges that equals the level of ionization within the chamber. The results on the digitizer are read out as the entrance surface dose after standard conversion from energy to dose.

Data Analysis

The data collected was analyzed using the statistical package for social sciences (SPSS) with both descriptive and inferential statistics. The mean and standard deviation of the anthropometric variables, technical parameters, and radiation dose received were analyzed. Correlation analysis with the Pearson's correlation coefficients (1.00=perfect correlation; 0= no correction) was used to determine the relationship between the different mammographic exposure parameters. The statistical significance was set at $P < 0.001$.

The linear regression test was also used to determine the relationship between the variables and to detect patterns in the data set.

RESULTS AND DISCUSSION

Table 1 shows the different specifications of each mammogram machine according to their target/filter combinations with the kVp and mAs ranges. The choice of target/filter combination determines the amount of radiation deposited by the mammography machine. The target/filter combination ranges from Tungsten/Rhodium, Molybdenum/Molybdenum to Molybdenum/Rhodium

with more mammogram machines used in the study having a target/filter combination of Molybdenum/Molybdenum. Rhodium/Molybdenum combination is not appropriate because Rhodium (atomic number of 45) has a higher penetrating beam (producing characteristic radiation at energy level of 20.3 keV and 22.7keV) than the Molybdenum (atomic number of 42) filters whose absorption is at energy level 20.3keV; and this will lead to further exposure of the patient breast to higher doses of radiation. Moreover, Rhodium is usually selected as a target when imaging denser breasts since the breast composition will require a high penetrating beam.

Table 1: Specification of Each Mammography Machine

Centres	Model	Target	Filter	kVp range	mAs range
1	Metaltronical SpA	Tungsten	Rhodium	22-32	5-400
2	Metaltronical Medivation	Molybdenum	Rhodium	22-32	0-600
3	Varian	Molybdenum	Molybdenum	22-40	5-500
4	Phillips	Molybdenum	Rhodium	22-35	0-600
5	Senographe Pristina	Tungsten		25-40	4-600

The correlation between the MGD values taken from the mammogram machine DICOM (Digital Imaging Communications in Medicine Header) and the measured values using the RadCal Accu-gold Detector Ionization chamber for the five mammography machines in the different five centres within Southwest Nigeria are seen on table 2. It was observed that the detector recorded higher values for the MGD per film ranging from 0.82 ± 0.22 to 1.66 ± 0.78 mGy for CC views and 0.99 ± 0.32 to 1.95 ± 0.93 mGy for MLO views; while the values for MGD per patients range from 2.49 ± 1.32 to 6.99 ± 3.88 mGy. The MGD values from the detector were slightly

high for the two projections unlike the values taken from the DICOM header where the MGD values per film ranged from 0.64 ± 0.14 to 1.59 ± 0.76 mGy for CC projections and 1.10 ± 0.52 to 1.55 ± 1.48 mGy for MLO projections; while the values for MGD per patient ranged from 1.98 ± 0.84 to 5.94 ± 2.78 mGy. This may be due to the fact that some exposure factors like the compression contributed to the low dose recorded by the mammogram machine in the DICOM header. The result of this study agrees with that of Supawitoo et. al (2006) where a 6-cc ionization chamber with an electrometer was used to obtain MGD from routine mammography.

Table 2: Comparison Between the Measured MGD and Machine MGD

		Mean $\pm$ SD Per Film (mGy)	Mean $\pm$ SD PerPatient (mGy)
Measured MGD (Radcal)	C1 CC-	1.34 ± 0.88	6.99 ± 3.88
	MLO-	1.55 ± 0.97	
	C2 CC-	1.54 ± 0.66	
	MLO-	1.95 ± 0.93	6.43 ± 4.02
	C3 CC-	1.66 ± 0.78	
	MLO-	1.88 ± 0.83	
	C4 CC-	1.55 ± 0.72	6.53 ± 3.59
	MLO-	1.57 ± 0.55	
	C5 CC-MLO-	0.82 ± 0.22	
Machine MGD (DICOM)		0.99 ± 0.32	2.49 ± 1.32
	C1CC-MLO-C2	1.02 ± 0.20	4.29 ± 0.70
	CC-MLO-C3	1.13 ± 0.50	
	CC-MLO-C4	1.42 ± 1.30	
	CC-MLO-C5	1.55 ± 1.48	5.94 ± 2.78
	CC-MLO-	1.59 ± 0.76	
		1.35 ± 0.44	
		0.64 ± 0.14	5.88 ± 1.20
		1.33 ± 0.12	

Mean±SD Per Film (mGy)	Mean±SD PerPatient (mGy)
0.88±0.32	1.98±0.84
1.10±0.52	

Figure 1: shows the Pearson correlation between measured mgd and machine mgd for the cc view suggesting a moderate positive association ($r = 0.453$), indicating that higher measured doses tended to correspond with higher machine-reported doses. However, this relationship was not statistically significant ($p = 0.444$), and the confidence interval was wide and included zero, suggesting considerable uncertainty in the estimate and insufficient evidence of a reliable linear association in the CC view.

For the MLO view, a strong positive correlation was observed between Measured MGD and Machine MGD ($r = 0.829$), implying substantial agreement between measured and machine-derived dose estimates. Despite the magnitude of this correlation, the association did not reach statistical significance ($p = 0.083$), and the confidence interval included zero. This indicates that, although the relationship appears strong, the available data do not provide sufficient statistical evidence to confirm a consistent association.

When CC and MLO observations were combined, the correlation between Measured MGD and Machine MGD remained positive and of moderate strength ($r = 0.581$).

This suggests an overall tendency toward agreement between measured and machine-reported doses across views. Nevertheless, the association was not statistically significant ($p = 0.078$), and the confidence interval again crossed zero, reflecting limited precision and likely reduced power due to the small sample size.

The comparison between CC and MLO results for Measured MGD demonstrated a very strong positive correlation ($r = 0.931$), indicating high consistency of measured glandular dose values across views. This association was statistically significant ($p = 0.021$), and the confidence interval excluded zero, providing strong evidence that measured MGD values are highly reproducible between CC and MLO projections.

In contrast, the correlation between CC and MLO results for Machine MGD was moderate and positive ($r = 0.520$), suggesting some level of agreement between machine-reported doses across views. However, this relationship was not statistically significant ($p = 0.369$), and the confidence interval was wide and included zero, indicating that the evidence is insufficient to conclude a reliable association for machine-derived MGD values between CC and MLO views.



Plate 1: Radcal 10X6-6M Mammography Ionization Chamber in a Chest Block

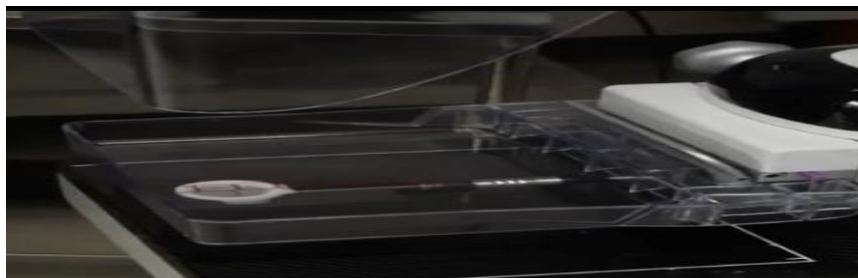


Plate 2: Ionization Chamber in Between the Compression Paddle and Breast Stand

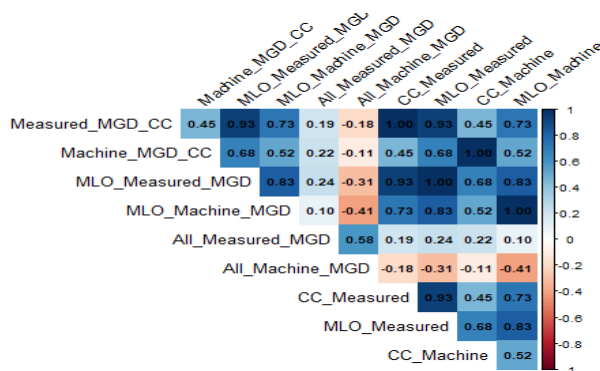


Figure 1: Correlation Between DICOM Data and Measured MGD Values

CONCLUSION

The MGD values measured by the Accu-Gold Ionization chamber were relatively higher when compare to the estimated MGD values from the DICOM header of the mammography machines. This may be due to the fact that some exposure factors like the compression contributed to the low dose recorded by the mammogram machine in the DICOM header. Generally, this study established the reliability of the MGD values estimated using the Dance formula by the mammography machines within Southwest Nigeria.

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CONFLICT OF INTEREST

Authors declare no conflict of interest.

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