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Mean Glandular Dose (MGD) Assessment of Patients Submitted for Mammography Examinations in Some Selected Radiological Facilities in Jos, Plateau State.

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ABSTRACT

Background: Mammography is the most effective imaging modality for early detection of breast cancer, but it involves ionizing radiation exposure to radiosensitive breast tissue. The mean glandular dose (MGD) is the most appropriate metric for assessing radiation risk in mammography.

Objective: This study aimed to evaluate patient-specific MGD values from craniocaudal (CC) and mediolateral oblique (MLO) views in selected radiological facilities in Jos, Plateau State, Nigeria, and compare them with international safety standards.

Methods: Twenty female patients underwent mammography examinations in two facilities (M1 and M2). Compressed breast thickness (CBT), exposure parameters, and incident air kerma were recorded. MGD was calculated using the Dance model with appropriate conversion coefficients.

Results: At M1, CBT ranged from 21.0-44.2 mm (mean 29.7 mm) with a mean MGD of 1.14 mGy. At M2, CBT ranged from 21.2-43.4 mm (mean 32.5 mm) with a mean MGD of 1.09 mGy. Both values were below the International Atomic Energy Agency (IAEA) reference level of 1.5 mGy for a 32 mm breast thickness.

Conclusion: The evaluated facilities operate within international safety standards, with patient doses comparable to global benchmarks. This study provides the first patient-based MGD assessment in Jos Plateau State and highlights the importance of continuous dose monitoring to optimize mammography practice in Nigeria.

Keywords: Mean glandular dose (MGD), Mammography, Compressed breast thickness (CBT), Radiation dose assessment, Patient safety

INTRODUCTION

Mammography remains the most effective imaging modality for the early detection of breast cancer, a disease that continues to be a leading cause of morbidity and mortality among women worldwide [2, 12]. However, because mammography employs ionizing radiation, concerns persist regarding the potential risk of radiation-induced breast cancer, particularly given the radiosensitivity of glandular breast tissue [1]. The mean glandular dose (MGD) is the most appropriate metric for quantifying radiation risk in mammography, as it represents the absorbed dose averaged over the fibroglandular tissue of the breast [11]. Although MGD cannot be measured directly, it can be estimated using compressed breast thickness (CBT), incident air kerma, and appropriate

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

conversion coefficients [6]. International guidelines, including those of the International Commission on Radiological Protection (ICRP) [7], and the International Atomic Energy Agency (IAEA) [9], recommend that patient radiation doses should be kept as low as reasonably achievable (ALARA principle) while maintaining clinically acceptable mammography practice. For mammography, the IAEA specifies that the achievable MGD should be ≤ 1.0 mGy and the acceptable level ≤ 1.5 mGy for a standard breast thickness of 32 mm [3]. Several studies across Europe, Asia, and the Middle East have reported MGD values in clinical practice, highlighting variations due to equipment type, exposure parameters, and patient characteristics [5, 4, 10, 1]. However, to the best of our knowledge, no patient-based MGD assessment has been conducted in Jos Plateau State, Nigeria. This represents a critical gap, as local data are essential for evaluating radiation safety, optimizing imaging protocols, and benchmarking against international standards.

Therefore, the present study aimed to determine patient-specific MGD values from craniocaudal (CC) and mediolateral oblique (MLO) views in selected radiological facilities in Jos Plateau State. By comparing these values with IAEA reference levels, this study provides the first baseline assessment of mammography radiation doses in the region and contributes to the broader effort of ensuring safe and effective breast cancer screening practices in Nigeria.

MATERIALS AND METHODS

Study Design and Setting: This cross-sectional study was conducted in two radiological facilities in Jos Plateau State, Nigeria. Both centers routinely perform screening and diagnostic mammography. Data collection was carried out over a two-month period, with ethical approval obtained from the University of Jos and Jos University Teaching Hospital Research Ethics Committees.

Patient Selection: A total of 20 female patients aged 33–57 years (mean age: 44 ± 6 years) undergoing routine mammography were recruited. Inclusion criteria were: (i) adult female patients referred for mammography, (ii) absence of prior breast surgery or implants, and (iii) provision of informed consent. Patients with incomplete exposure records or technical errors were excluded.

Mammography Procedure: Each patient underwent four standard views: right craniocaudal (RCC), left craniocaudal (LCC), right mediolateral oblique (RMLO), and left mediolateral oblique (LMLO). Examinations were performed using dedicated mammography units with automatic exposure control. Exposure parameters (tube voltage (kVp), tube current–time product (mAs), and compressed breast thickness (CBT) were recorded for each view.

Mammography Unit Specifications and Quality Control: Mammography examinations were performed using dedicated full-field digital mammography systems installed at the two selected radiological facilities (M1 and M2).

Table 1: Mammography Equipment Specifications and Quality Control Status of the Evaluated Facilities

S/N	PARAMETER	FACILITY M1	FACILITY M2
1	**Manufacturer**	General Electric	Siemens
2	**Model**	Senographe 800T	Mammomat
3	**Serial Number**	2299553	08597-S11
4	**Year Manufactured**	December 2004	May 2000
5	**Year Installed**	November 2019	March 2022
6	**Detector Type**	Indirect Conversion (Flat Panel)	Indirect Conversion (Flat Panel)
7	**Maximum Tube Voltage (kVp)**	35	35
8	**Maximum Tube Current-Time Product (mAs)**	600	560
9	**Target/Filter Combination**	Mo/Mo, Mo/Rh, Rh/Rh	Mo/Mo, Mo/Rh, Rh/Rh
10	**Automatic Exposure Control (AEC)**	Standard	Standard
11	**Half-Value Layer (HVL)**	0.69 mmAl	30 µm Mo / 25 µm Rh

12	**Last Calibration Date**	2022	2024
13	**Quality Control Status**	Optimal	Optimal

Dosimetric Assessment: The incident air kerma (Ki) values used for mean glandular dose estimation were obtained directly from the mammography unit console display for each projection. Independent verification using an external calibrated dosimeter was not performed during the study period. However, the mammography systems were operating under routine quality assurance conditions within the facilities at the time of data collection. Mean glandular dose (MGD) was calculated using the Dance model; the conversion coefficients (g, c, and s) were selected according to the Dance dosimetry protocol based on compressed breast thickness (CBT), beam quality, and target/filter combination. The formula applied was:

$$MGD = K_i \times g \times c \times s \qquad (1)$$

where K_i is the incident air kerma (in mGy), g is a conversion factor from K_i to MGD for breast with 50% glandularity, c is a correction factor for any difference in glandularity other than 50 %, s is a correction factor for any difference in the x-ray spectrum produced by a tube with molybdenum anode and filter. The g factor converts incident air kerma to mean glandular dose for a standard breast composition, c corrects for differences in breast glandularity, while s accounts for variations in the X-ray spectrum associated with the target/filter combination [6].

Data Analysis: All data were entered into Microsoft Excel and analyzed using descriptive statistics. Results were expressed as mean ± standard deviation (SD). Comparisons between facilities and views were performed using Student's t-test, with statistical significance set at $p < 0.05$.

RESULTS AND DISCUSSION

A total of 20 female patients (ages 33–57 years, mean 44 years) underwent mammography examinations across two facilities (M1 and M2). Four standard views; right craniocaudal (RCC), left craniocaudal (LCC), right mediolateral oblique (RMLO), and left mediolateral oblique (LMLO) were analyzed for each patient.

Table 2: Patient-specific exposure parameters, incident air kerma, and calculated MGD for mammography examinations at Facility M1

S/N	PROJECTION	AGE (years)	CBT (mm)	kVp	mAs	FSD (mm)	g *x* c	S	Ki (mGy)	MGD (mGy)
1	RCC	54	22.3	28	52	627.7	0.336	1	3.57	1.20
	LCC	54	21.5	28	52	628.5	0.336	1	3.54	1.19
	RMLO	54	22.2	28	52	627.8	0.336	1	3.56	1.20
	LMLO	54	22.4	28	52	627.6	0.336	1	3.65	1.23
2	RCC	48	31.3	30	56	618.7	0.245	1	4.11	1.01
	LCC	48	31.5	30	56	618.5	0.245	1	4.11	1.01
	RMLO	48	32.7	30	56	617.3	0.245	1	4.19	1.03
	LMLO	48	32.4	30	56	617.6	0.245	1	4.14	1.01
3	RCC	43	33.5	30	56	616.5	0.245	1	4.91	1.20
	LCC	43	33.7	30	56	616.3	0.245	1	4.91	1.20
	RMLO	43	33.9	30	56	616.1	0.245	1	5.01	1.23
	LMLO	43	34.1	30	56	615.9	0.245	1	5.14	1.26
4	RCC	49	21.7	28	52	628.3	0.336	1	3.52	1.18
	LCC	49	22.1	28	52	627.9	0.336	1	3.65	1.23
	RMLO	49	22.9	28	52	627.1	0.336	1	3.56	1.20
	LMLO	49	22.7	28	52	627.3	0.336	1	3.61	1.21
5	RCC	49	22.9	28	52	627.1	0.336	1	3.62	1.22
	LCC	49	23.4	28	52	626.6	0.336	1	3.70	1.24
	RMLO	49	22.2	28	52	627.8	0.336	1	3.65	1.23

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

	LMLO	49	23.4	28	52	626.6	0.336	1	3.72	1.25
6	RCC	33	41.5	30	60	608.5	0.195	1	5.05	0.98
	LCC	33	40.4	30	60	609.6	0.195	1	5.00	0.98
	RMLO	33	43.7	30	60	606.3	0.195	1	5.77	1.13
	LMLO	33	44.2	30	60	605.8	0.195	1	5.90	1.15
7	RCC	41	21.0	28	52	629.0	0.336	1	3.50	1.18
	LCC	41	21.1	28	52	628.9	0.336	1	3.50	1.18
	RMLO	41	22.2	28	52	627.8	0.336	1	3.54	1.19
	LMLO	41	22.3	28	52	627.7	0.336	1	3.54	1.19
8	RCC	37	33.3	30	56	616.7	0.245	1	4.42	1.08
	LCC	37	33.5	30	56	616.5	0.245	1	4.42	1.08
	RMLO	37	33.7	30	56	616.3	0.245	1	4.45	1.09
	LMLO	37	33.9	30	56	616.1	0.245	1	4.49	1.10
9	RCC	43	32.0	30	56	618.0	0.245	1	4.07	1.00
	LCC	43	32.1	30	56	617.9	0.245	1	4.18	1.02
	RMLO	43	32.7	30	56	617.3	0.245	1	4.19	1.03
	LMLO	43	33.0	30	56	617.0	0.245	1	4.24	1.04
10	RCC	35	33.5	30	56	616.5	0.245	1	4.32	1.06
	LCC	35	33.4	30	56	616.6	0.245	1	4.32	1.06
	RMLO	35	33.7	30	56	616.3	0.245	1	4.77	1.17
	LMLO	35	34.1	30	56	615.9	0.245	1	4.90	1.20

Table 2b: Summary statistics

parameters	**AGE (years)**	**CBT (mm)**	**kVp**	**mAs**	**FSD (mm)**	**g *x* c**	**S**	**Ki (mGy)**	**MGD (mGy)**
MAXIMUM	**54**	**44.2**	**30**	**60**	**629.0**	**0.336**	**1**	**5.90**	**1.26**
MINIMUM	**33**	**21.0**	**28**	**52**	**605.8**	**0.195**	**1**	**3.50**	**0.98**
MEAN	**43**	**29.7**	**29**	**55**	**620.3**	**0.276**	**1**	**4.21**	**1.14**

The Patient-specific incident air kerma and calculated mean glandular dose (MGD) for various mammography views at M1 is presented in Table 2.

Patient data and exposure factors for mammography investigations at M2 are shown in Table 2. From Table 2, it was observed that the age of the women presented at M2 for mammography investigations ranged from 39 to 57years with a mean age of 45years. The CBT for this facility was found to have a minimum of 21.2mm and a maximum of 43.4mm having a mean value of 32.5mm. The applied voltage (kVp) and current (mAs) were from 28-30kVp and 52-60mAs respectively while the mean applied was 29 kVp and the mean current was 56mAs. The MGD for various mammography views at M2 are shown in Table 4. From the Table 4, the individual MGD obtained were between 0.96mGy to 1.30mGy with a mean of 1.09mGy across the investigated patients at M2.

Table 3: Patient-specific exposure parameters, incident air kerma, and calculated MGD for mammography examinations at Facility M2

S/N	PROJECTION	AGE (years)	CBT (mm)	kVp	mAs	FSD (mm)	g *x* c	S	Ki (mGy)	MGD (mGy)
1	RCC	41	31.5	30	56	618.5	0.245	1	4.15	1.02
	LCC	41	32.4	30	56	617.6	0.245	1	4.14	1.01
	RMLO	41	31.3	30	56	618.7	0.245	1	4.15	1.02
	LMLO	41	32.3	30	56	617.7	0.245	1	4.14	1.01
2	RCC	43	30.9	30	56	619.1	0.245	1	3.91	0.96
	LCC	43	32.1	30	56	617.9	0.245	1	4.10	1.00
	RMLO	43	30.3	30	56	619.7	0.245	1	4.90	1.20

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

	LMLO	43	32.3	30	56	617.7	0.245	1	4.11	1.01
3	RCC	39	43.1	30	60	606.9	0.195	1	5.51	1.07
	LCC	39	43.4	30	60	606.6	0.195	1	5.57	1.09
	RMLO	39	43.0	30	60	607.0	0.195	1	5.50	1.07
	LMLO	39	43.4	30	60	606.6	0.195	1	5.96	1.16
4	RCC	45	32.3	30	56	617.7	0.245	1	4.15	1.02
	LCC	45	32.7	30	56	617.3	0.245	1	4.13	1.01
	RMLO	45	33.0	30	56	617.0	0.245	1	4.21	1.03
	LMLO	45	32.3	30	56	617.7	0.245	1	4.14	1.01
5	RCC	40	41.1	30	60	608.9	0.195	1	5.09	0.99
	LCC	40	40.7	30	60	609.3	0.195	1	5.00	0.98
	RMLO	40	41.9	30	60	608.1	0.195	1	5.22	1.02
	LMLO	40	42.0	30	60	608.0	0.195	1	5.25	1.02
6	RCC	49	21.2	28	52	628.8	0.336	1	3.53	1.19
	LCC	49	22.4	28	52	627.6	0.336	1	3.60	1.21
	RMLO	49	22.0	28	52	628.0	0.336	1	3.59	1.21
	LMLO	49	23.4	28	52	626.6	0.336	1	3.69	1.24
7	RCC	44	25.9	28	52	624.1	0.336	1	3.86	1.30
	LCC	44	25.5	28	52	624.5	0.336	1	3.84	1.29
	RMLO	44	25.0	28	52	625.0	0.336	1	3.80	1.28
	LMLO	44	25.4	28	52	624.6	0.336	1	3.85	1.29
8	RCC	41	41.5	30	60	608.5	0.195	1	5.21	1.02
	LCC	41	43.1	30	60	606.9	0.195	1	5.49	1.07
	RMLO	41	42.2	30	60	607.8	0.195	1	5.27	1.03
	LMLO	41	43.0	30	60	607.0	0.195	1	5.42	1.06
9	RCC	52	32.5	30	56	617.5	0.245	1	4.21	1.03
	LCC	52	32.7	30	56	617.3	0.245	1	4.14	1.01
	RMLO	52	32.1	30	56	617.9	0.245	1	4.19	1.03
	LMLO	52	32.7	30	56	617.3	0.245	1	4.14	1.01
10	RCC	57	21.7	28	52	628.3	0.336	1	3.54	1.19
	LCC	57	22.0	28	52	628.0	0.336	1	3.57	1.20
	RMLO	57	22.0	28	52	628.0	0.336	1	3.59	1.21
	LMLO	57	22.4	28	52	627.6	0.336	1	3.61	1.21

Table 3b: Summary statistics

parameters	**AGE (years)**	**CBT (mm)**	**kVp**	**mAs**	**FSD (mm)**	**g *x* c**	**S**	**Ki (mGy)**	**MG**
MAXIMUN	**57**	**43.4**	**30**	**60**	**628.8**	**0.336**	**1**	**5.96**	**1.30**
MINIMUM	**39**	**21.2**	**28**	**52**	**606.6**	**0.195**	**1**	**3.53**	**0.96**
MEAN	**45**	**32.5**	**29**	**56**	**617.5**	**0.257**	**1**	**4.39**	**1.09**

The mean CBT values for various mammogram views at the two radiology facilities (M1 and M2) were compared in a chart as presented in Figure 1.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

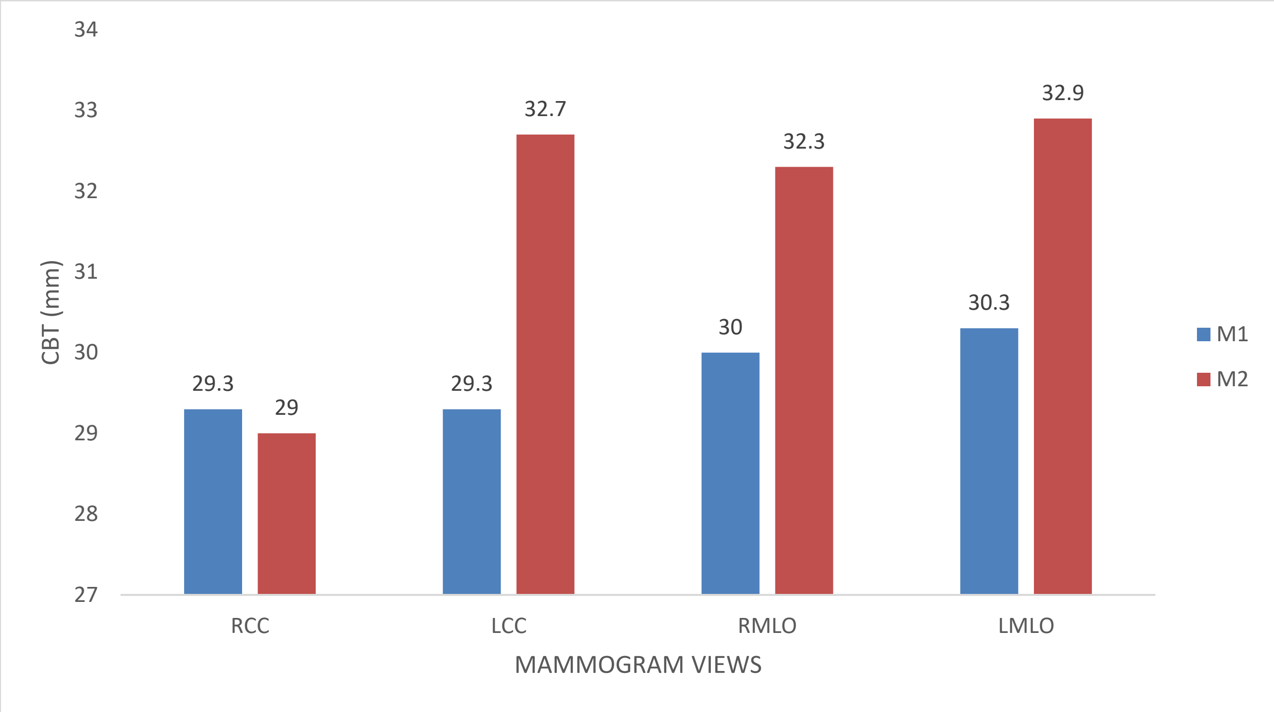

Figure 1: The mean CBT values for various mammogram views at the two radiology facilities.

The mean CBT values at M1 were 29.3, 29.3, 30.0 and 30.3mm corresponding to RCC, LCC, RMLO and LMLO mammogram views respectively. While the mean CBT observed at M2 are 29.0, 32.7, 32.3 and 32.9 corresponding to RCC, LCC, RMLO and LMLO mammogram views respectively. The mean CBT observed at M1 shows gradual increase such that RCC>LCC>RMLO>LMLO with a variation between the right breast thickness and that of the left breast. Similarly, M2 also showed an increasing trend from RCC to LMLO, except for the RMLO projection. A sharp increase in the mean CBT was observed for the LCC vie at M2 when compared to the corresponding RCC. The average kVp across the various views was the same at M1 with a value 29.2kVp, similarly M2 shows the same applied voltage of 29.4kVp except for the RCC view which was 3kVp lower as shown in Figure 2.

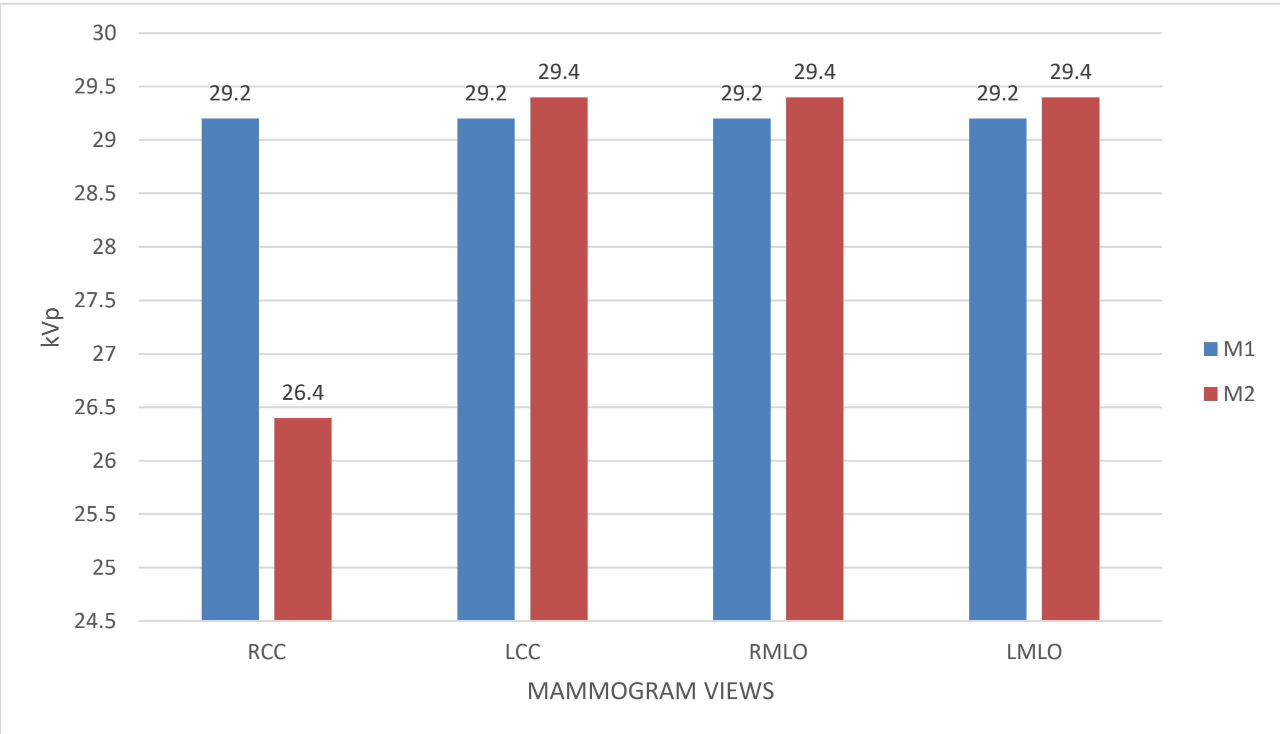

Figure 2: The mean kVp values for various mammogram views at the two radiology facilities.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

Figure 3 shows the mean mAs values for various mammogram views at the two radiology facilities. The mAs for M2 was the same for LCC, RMLO and LMLO having a value of 56mAs except for RCC with 50mAs as shown in Figure 3. The difference in mAs in both M1 and M2 for all four mammogram views was 1mAs except for the RCC at M2 with a difference of 5mAs.

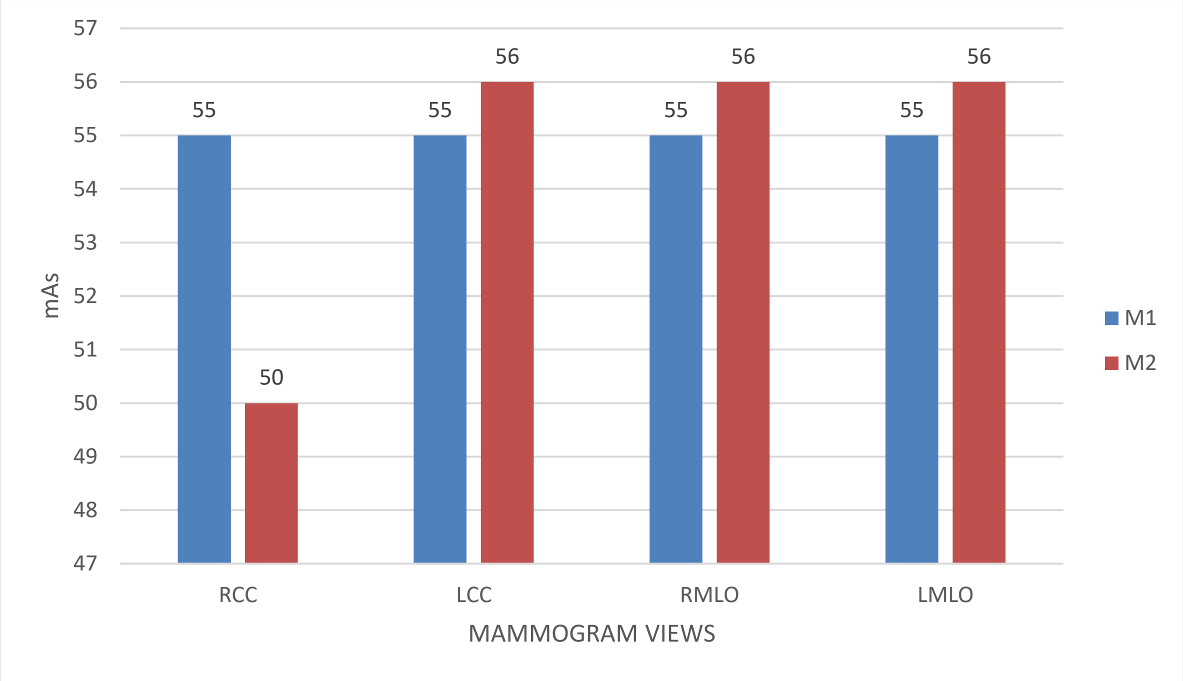

Figure 3: The mean mAs values for various mammogram views at the two radiology facilities.

The respective MGD values for the RCC, LCC, RMLO and LMLO mammogram views across M1 and M2 are represented on Figure 4. All the mammographic views at M1 exhibited slightly higher MGD values than the corresponding views at M2. M2 shows an increase in MGD such that RCC > LCC > RMLO > LMLO. This was also true for M1 except for LMLO that shows a slight drop of 0.01mGy. The MGD values for RCC, LCC, RMLO and LMLO at M1 were 1.11, 1.12, 1.15 and 1.16mGy, respectively, while the corresponding values at M2 were 1.08, 1.09, 1.11 and 1.10mGy for RCC, LCC, RMLO and LMLO respectively.

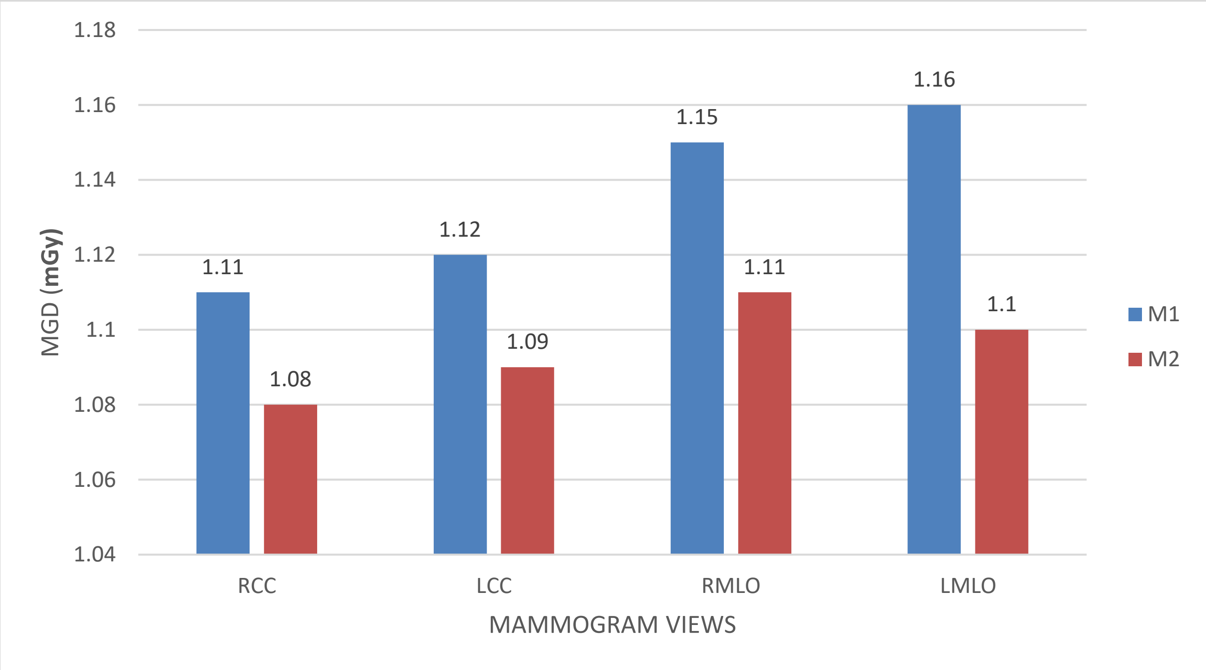

Figure 4: The MGD values for various mammogram views at the two radiology facilities.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

The facility specific mean glandular dose is shown in Table 3. The MGD of each facility was compared to international atomic energy agency (IAEA) standard.

Table 3: The comparison of the obtained MGD in this study to standard value.

FACILITY	MEAN CBT (mm)	MGD (mGy)	IAEA Acceptable MGD (mGy)	IAEA Achievable MGD (mGy)	REMARK
M1	29.7	1.14	1.5	1	PASSED
M2	32.5	1.09	1.5	1	PASSED

A total of twenty (20) female patients aged 33-57 years (mean age: 44 ± 6 years) participated in this study across two radiological facilities (M1 and M2). Each patient underwent four standard mammographic projections: right craniocaudal (RCC), left craniocaudal (LCC), right mediolateral oblique (RMLO), and left mediolateral oblique (LMLO), resulting in a total of 80 mammographic projections analyzed. At facility M1, the compressed breast thickness (CBT) ranged from 21.0-44.2 mm with a mean value of 29.7 mm, while the applied tube voltage and tube current-time product ranged from 28-30 kVp and 52-60 mAs, respectively. The calculated mean glandular dose (MGD) ranged from 0.98-1.26 mGy with an average value of 1.14 mGy. At facility M2, the CBT ranged from 21.2-43.4 mm with a mean value of 32.5 mm. Exposure parameters ranged from 28-30 kVp and 52-60 mAs, respectively, while the calculated MGD ranged from 0.96-1.30 mGy with a mean value of 1.09 mGy. Exposure parameters were automatically optimized using the automatic exposure control (AEC) system based on breast thickness and attenuation characteristics. The obtained MGD values for both facilities were below the International Atomic Energy Agency (IAEA) acceptable reference level of 1.5 mGy for a standard breast thickness of 32 mm, indicating that the evaluated facilities operated within recommended dose limits for the studied patient population.

DISCUSSION

The present study assessed patient-specific mean glandular doses (MGD) in two radiological facilities in Jos, Plateau State, Nigeria. The findings revealed mean MGD values of 1.14 mGy (M1) and 1.09 mGy (M2), both below the International Atomic Energy Agency (IAEA) reference level of 1.5 mGy for a compressed breast thickness of 32 mm [3]. These results confirm that the facilities operate within international radiation safety standards and provide reassurance regarding patient protection during mammography examinations. The observed MGD values are consistent with reports from other regions. For example, Ciraj-Bjelac et al. (2010) [5] reported mean MGDs of 1.2-1.5 mGy across European centers, while Bouzarjomehri et al. (2006) [4] found values ranging from 0.9-1.3 mGy in Iran. Similarly, Jamal et al. (2003) [10] documented MGDs around 1.1 mGy in clinical practice. The values obtained in the present study fall within this international range, suggesting that Nigerian facilities are aligned with global benchmarks despite differences in equipment and patient populations.

Maintaining MGD within recommended limits is critical, given the radiosensitivity of glandular breast tissue and the potential risk of radiation-induced cancer [1]. The facilities demonstrated mean glandular dose values within internationally recommended reference levels [7]. This has important implications for patient reassurance, quality assurance programs, and the optimization of exposure parameters in resource-limited settings.

CONCLUSION

This study demonstrated that mammography examinations performed in the investigated facilities in Jos, Plateau State, Nigeria, resulted in mean glandular doses that were within internationally accepted limits. The evaluated facilities demonstrated mean glandular dose values below the IAEA acceptable reference level for the studied patient population. The findings provide reassurance regarding patient safety while emphasizing the need for ongoing quality assurance and optimization of exposure parameters. As the first patient-based MGD assessment in this region, the study contributes valuable baseline data for Nigeria and supports benchmarking against global practices. However, the relatively small sample size and limited number of facilities represent constraints. Future research should expand to include larger populations, multiple centers, and phantom-based validation to strengthen dose optimization strategies and enhance patient protection in mammography services across the

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue VI June 2026

country.

Availability of data and material: The data obtained and analyzed are included within this work.

Competing interest: The authors declare that they have no known competing financial interests or personal relationships that could appear to influence the work.

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