



# Diagnostic Reference Levels (DRLs) and Image Quality Evaluation for Digital Mammography in a Nigerian Facility

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## Abstract

Diagnostic Reference Levels (DRLs) for digital mammography and image quality evaluation are important optimization tools in medical imaging. High quality mammograms are essential to the successful early detection of breast cancer. The objective of the study is to establish DRLs for digital mammography and to assess image quality of the mammograms for optimization. DRLs were established using thermoluminescent dosimeter (TLD) chips to estimate the mean glandular dose for both cranio-caudal and medio-lateral oblique projections. The TLD chips were calibrated. The DRLs were set at the 75th percentile of the distribution of the median value of mean glandular dose. Image quality was assessed using European Commission guideline for mammographic image quality assessment. Results for DRLs were 0.53 mGy for cranio-caudal and also 0.53 mGy for medio-lateral oblique. Image quality evaluation showed criteria scores for cranio-caudal and medio-lateral oblique projections as 76 % and 61.2 % respectively. The mammograms scored the highest and lowest score of 100 % and 44 % on criteria 2 and criteria 6 (absence of skin fold) respectively for cranio-caudal projections while for the mediolateral oblique projections, criteria 1 (all breast tissue clearly shown) and criteria 5 (inframammary angle clearly demonstrated) have the highest and lowest score of 96 % and 8 % respectively. The study showed that the DRLs in this study was lower than the established values in other regions of Nigeria and international established values. Image quality was within acceptable level. DRLs for digital mammography and image quality evaluation are important optimization tool that should be adopted by every radiology department with mammography unit.

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## 1. Introduction

Medical uses of ionizing radiation are among the longest established applications of ionizing radiation [1]. The risk associ-

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ated with medical use of ionizing radiation varies significantly depending strongly on the radiological procedure [2]. For medical exposure, the optimization of radiological protection is best described as management of the radiation dose to the patient to be commensurate with the medical purpose [3].

Diagnostic reference level is an important tool for optimization of protection. It is a quality assurance tool introduced in 1996 as a term for a form of investigation level used to identify situation where optimization of protection may be required in the medical exposure of the patient [4]. It is used in medical imaging to indicate whether in routine conditions, the radiation dose used for a specific radiological examination or the amount of radiopharmaceutical administered to a patient is unusually high or unusually low for that procedure [5]. Compliance with diagnostic reference value does not necessarily indicate image quality is adequate or that the examination is performed using optimal amount of radiation [5].

Mammography is a specialized non-invasive radiographic imaging of the breast tissue (soft tissue radiography) using low dose of x-ray. The breast is largely composed of two types of tissue, namely adipose (fatty) tissue and glandular/ fibroglandular tissue (including acinar and ductal epithelium and associated stroma) [6]. The goal of mammography is the early detection, characterization, and evaluation of findings suggestive of breast cancer and other breast diseases [7]. It is carried out on both symptomatic women with a known history or suspected abnormality of the breast and as a screening procedure in, asymptomatic women [8]. Patient dose and image quality are the main concerns in mammography particularly in screening mammography where comparison with former films is often essential. The accuracy of diagnosis is very dependent on the image quality [8]. Adequate quality dose is the current trend recommended by ICRP in the optimization of protection for patient undergoing mammography procedure. It is the recommended dose needed to produce images that meet the clinical needs of the patient. [8]. The glandular tissue that makes up the breast is one of the radiosensitive tissues in the human body. It is therefore imperative] to use the required amount of radiation to produce images that are clinically acceptable. Over-exposure of the breast to radiation may increase radiation induced carcinogenesis while under exposure may hide anatomical and pathological details needed to make proper diagnosis. Optimization process that encompasses both establishment of diagnostic reference level process and image quality evaluation should be encouraged and implemented in radiology facilities [8]. The role of the radiographer is central to the success of breast screening programme in producing high quality mammograms which are crucial for early diagnosis of breast cancer (EUREF, 2006a). The radiographic technique adopted by the radiographer has the greatest influence on the dose received by the glandular tissue of the breast and correct positioning techniques during mammography has been shown to improve breast cancer detection rates [9].

Diagnostic reference level and image quality evaluation are key components in the optimization of protection for patient undergoing mammography examination (ICRP, 2017) [10]. Establishment of diagnostic reference level for mammography and

image quality evaluation of mammographic images ensures that the required amount of radiation is used to produce clinically diagnostic images. Diagnostic reference level for 4 mammography if consistently exceeded calls for audit of the procedure in order to determine the cause of the higher doses and recommendation implemented urgently (EUREF, 2006a) [9]. In situation where the diagnostic reference level is unusually low, image quality may be compromised and there might be increased likelihood of repetition arising from poor image quality. The glandular tissues that make up the breast are very radiosensitive thus must be protected from unnecessary exposure to radiation. Diagnostic reference level (DRL) for mammography has been established in many parts of the world as a necessary tool for optimization of protection of patients undergoing mammography examination. In Nigeria, diagnostic reference level for mammography has been established in north –eastern Nigeria but diagnostic reference level specifically for digital mammography as well as image quality evaluation has not been done in any of the federal capital territory hospital. The purpose of this study is to establish diagnostic reference level for digital mammography and to evaluate image quality in Asokoro District Hospital in Abuja, Nigeria The outcome of this study, will serve as a clinical audit of mammography procedure in the selected hospital in order to promote good practice and dose optimization. It will further enhance training of Radiographers, Radiologist and Medical Physicist involved in the production of mammographic images, interpretation of images and quality assurance procedure through comparison of results with international established work. The research will add to the pool of data for the establishment of National and regional diagnostic reference level for mammography procedure. It will also serve as a comparative guide for practitioners, researchers and regulators.

## 2. Materials and Methods

### 2.1. Materials

General Electric Senograph Essential digital mammography machine manufactured June, 2011 with maximum  $kVp$  of 49, inherent filtration of 0.66  $Be$  and focal spot size of 0.1 – 0.3  $mm$  was used for the research. This machine is for generation of x-ray with low energy between 18 – 35  $kVp$  (Figure 1). The Thermoluminescent dosimeter chips are manufactured by Rad pro International Germany. They are MCP TLD chips and measure 3.2  $mm$  x3.3  $mm$  x0.9  $mm$ . Density 2.5  $g/cm^3$ . The chips are for measurement of incident air kerma and estimation of mean glandular dose. The TLD chips are made up of Lithium fluoride which is near tissue equivalent. The TLD chips were annealed and exposed for the purpose of generating reader calibration factors (RCF) for the reader and elemental correction coefficient (ECC) for each of the TLD chip. All exposures for the calibration of the reader and dosimeter were done at the National Institute of Radiation Protection research (NIRPR), University of Ibadan. TLD chips was also set aside as control to record the background radiation. The control TLD chips were kept away from every form of irradiation.

## 2.2. Data Collection

Data was obtained using prospective cross sectional approach involving fifty (50) Women who came for both screening and diagnostic mammography examinations within the period of the research June 2019 to December 2019. The women were between the ages of 40- 64 and consented to the research. Medio-lateral and cranio-caudal projections were obtained. Positioning for both projections was done by a radiographer in mammography. The machine uses automatic exposure control (AEC); therefore provided the exposure factors used automatically namely  $kVp$ ,  $mAs$ , anode/filter combination according to the breast granularity and thickness. The above parameters were recorded on a work sheet for the patients and projections. The exposed TLDs were labeled PTCC1-50 for cranio-caudal projections and PTMLO1-50 for medio-lateral oblique projections for proper identification and kept in black nylon away from radiation.

## 2.3. Estimation of Doses

The TLD chips were read with a reader HARSHAW model 3500. The values obtained were subtracted from the control TLD value to give the value of the incident air kerma used for each patient and view. To estimate the mean glandular dose, the conversion factors from the works of Dance [10] and Dance *et al* [12, 13], were used to calculate the mean glandular dose (MGD) for both cranio-caudal and medio-lateral oblique projections of the breast.

$$MGD = Kgc_s, \quad (1)$$

Where  $K$  is the incident air kerma obtained at the upper quadrant of the breast without back scatter;  $g = K$  to  $MGD$  conversion factor on the assumption that the entire breast has a glandularity 50 %,  $c$  is the conversion factors for difference in breast composition other than 50 % glandularity,  $s =$  conversion factor for different X-ray spectrum which can be due to different anode/filter combination, for example,  $Mo/Mo$ ,  $Mo/Rh$ ,  $Rh/Rh$ .

The total mean glandular dose for both cranio-caudal and medio-lateral oblique projections was calculated using the statistical package for social science version 21.0 and the formula is given as

$$\bar{X} = \frac{\sum x}{n}, \quad (2)$$

where  $n =$  number of patients,  $x =$  mean glandular dose for each view,  $\bar{X} =$  mean glandular dose for cranio-caudal and medio-lateral oblique projections respectively.

## 2.4. Establishment of Diagnostic Reference Level

The DRL was set at the 75th percentile (Third quartile) distribution of the median glandular dose for both cranio-caudal and medio-lateral oblique projection.

## 2.5. Image Quality Evaluation

Image quality evaluation was carried out by the researcher and two specialist radiographers in mammography using the EC criteria for image quality evaluation for mammography. Absolute grading score of yes (1) or no (0) were used for the criteria. Scores were converted to percentages for each of the patient for cranio-caudal and medio-lateral projections. Number of patients mammogram that met each criterion were also assessed and converted to percentages.

## 3. Results

The data from Table 2 show that the mean values for incident air kerma and direct digital mammography reading for both cranio-caudal and medio-lateral oblique projections are 2.05  $mGy$ , 1.99  $mGy$  and 0.46  $mGy$ , 0.46  $mGy$ , respectively.

Using the data obtained in Table 2, the mean glandular doses for each both cranio-caudal and medio-lateral oblique projection were calculated using equation 1 and the total mean glandular dose for cranio-caudal and medio-lateral oblique projections were calculated using equation 2. The total mean glandular dose for cranio-caudal projection was  $0.46 \pm 0.07$   $mGy$  while the total mean glandular dose for medio-lateral oblique projections was  $0.46 \pm 0.11$   $mGy$ . The median value for both cranio-caudal and medio-lateral oblique projections was 0.47  $mGy$ .

The Local diagnostic reference level for TLD was set at the 75th percentile of the distribution of the mean glandular dose. Statistical package for social science was used to obtain the 75th (3rd quartile) percentile values of the mean glandular dose. The TLD value was found to be 0.53  $mGy$  for cranio-caudal oblique and also 0.53  $mGy$  for medio-lateral oblique projections, while that of DDMR is 1.46  $mGy$  and 1.46  $mGy$ .

Table 3 and 4 Image quality was assessed using European guidelines for image quality assessment. The scores obtained were converted to percentages. The mammograms scored the highest and lowest score of 100 % and 44 % on criteria 2 (as much as possible of the lateral aspect of the breast is shown) and criteria 6 (absence of skin fold) respectively for cranio-caudal projections while for the mediolateral oblique projections, criteria 1 (all breast tissue clearly shown) and criteria 5 (inframammary angle clearly demonstrated) have the highest and lowest score of 96 % and 8 % respectively. The total average score of the mammogram for cranio-caudal and medio-lateral oblique projections are 76 and 61.2 %, respectively.

## 4. Discussion

The research has established a facility based diagnostic reference level for digital mammography and image quality evaluation in a selected hospital under Federal Capital Territory administration. Based on the findings, the total mean glandular dose using thermoluminescent dosimeters for cranio-caudal and medio-lateral oblique view of the breast are  $0.46 \pm 0.07$   $mGy$  and  $0.46 \pm 0.11$   $mGy$  respectively, which is within the recommended value (2.5  $mGy$  and not more than 3  $mGy$ ) given by EUREF [8]. The result of the current study is in line with studies done

Table 1. Demographic distribution of patients.

Variable	Number of Patients	Percentage (%)
<b>Age</b>		
40-45 years	28	56.0
45-55 years	18	36.0
56-64 years	4	8.0
<b>Body mass</b>		
51-70 kg	7	14.0
71-90 kg	27	54.0
91-110 kg	14	28.0
111-130 kg	2	4.0

Table 2. Mean Distribution of Incident Air Kerma (IAK) and Direct Digital Mammography Reading (DDMR) for CC and MLO.

Mean	CBT(mm)		(mGy)	
	CC	MLO	CC	MLO
TLD IAK	57.34	56.36	2.05	1.99
DDMR	57.34	56.36	0.46	0.46

Table 3. Local Diagnostic Reference level for the Hospital.

	CC(mGy)	MLO(mGy)
TLD	0.52	0.52
DDMR	1.46	1.46

by Joseph *et al.* [15], Joshua *et al.* [16] and Ogundare *et al.* [17] who estimated mean glandular doses for cranio-caudal and medio-lateral oblique projections using TLD chips.

Findings from the comparison of DICOM mean glandular dose values and TLD mean glandular dose values show significant difference in the two methods of data collection. The DICOM mean glandular dose values were found to be 1.30 and 1.36 *mGy* for cranio-caudal and medio-lateral oblique view respectively. While the TLD mean glandular dose values were 0.46 *mGy* for both cranio-caudal and medio-lateral projections respectively, which difference in conversion factors used by different vendors of mammography units may be responsible. The value obtained for DICOM mean glandular dose is similar to the work by researchers who used the dose values on the DICOM viewer to obtain the mean glandular dose.

Diagnostic Reference Level obtained by TLD calculations are 0.52 and 0.52 *mGy* for cranio-caudal and medio-lateral oblique view respectively. While the 75th percentile of distribution of the mean glandular dose obtained from the DICOM viewer of the digital machine are 1.46 and 1.46 *mGy* for cranio-caudal and medio-lateral oblique. The findings reveal that the DRL (Diagnostic Reference Level) obtained from this study using TLD chips is slightly lower when compared to work by Joseph *et al.* [15]. This might be due to combination of screen film mammography and digital mammography unit and the output of the machines. Digital units are known to use lower dose when compared with screen film unit. The value obtained is however within the recommended range for both TLD and DICOM values.

The image quality was evaluated using European guideline



Figure 1. GE Senograph Essential Digital Mammography Unit.



Figure 2. TLD Chips.

for image quality assessment for both cranio-caudal and medio-lateral projections of the mammograms. For the cranio-caudal projection, 42 (84 %) of the mammograms have the medial border of the breast shown. 50 (100 %) have much as possible lateral aspect of the breast shown. 40 (80 %) of the mammogram have the pectoral muscle shadow shown at the posterior

Table 4. Mammogram Image Quality Evaluation for Cranio-caudal view (CC).

Criteria for assessment	No. of Mammograms	Percentage (%)
The medial border of the breast is shown	42	84
As much as possible of lateral aspect of the breast is shown	50	100
If possible, the pectoral muscle shadow is shown on the posterior edge of the breast	40	80
The nipple is in profile	26	52
Symmetrical images of both breast	46	92
Absence of skin fold	22	44

Table 5. Mammogram Image Quality Evaluation for Medio-lateral oblique view (MLO).

Criteria for assessment	No. of Mammograms	Percentage (%)
All breast tissue clearly shown	48	96
Pectoral muscle to nipple level	40	80
Symmetrical images of both breast	46	92
Nipple in profile	18	36
Inframammary angle clearly demonstrated	4	8

Table 6. Comparison of Dose Values with other Established Works .

Researcher	TLD MGD (mGy)		TLD DRL (mGy)	
	CC	MLO	CC	MLO
Current study	0.46	0.46	0.53	0.53
Joseph <i>et al.</i> [15]	0.31	0.69	0.63	1.04
Joshua <i>et al.</i> [16]	0.25	0.51	-	-
Ogundare <i>et al.</i> [17]	0.33	1.43	-	-

edge of the breast. 26 (52 %) of the mammograms have the nipple in profile, the inability to achieve a higher percentage of this criteria might be due to patients with retracted nipple and poor positioning techniques. 46 (92 %) of the mammograms have symmetrical images of both breast while 22 (44 %) of the mammogram have no skin. The mean glandular doses and diagnostic reference levels obtained from this study, are in line with the works done by Joseph *et al.* [15] that established DRLs for mammography in North-Eastern Nigeria. The mean glandular doses obtained from this study is also in tandem with the findings of Joseph *et al.* [15, 16] and Ogundare *et al.* [17].

The absence of skin fold has the lowest percentage achieved criteria. This could be attributed to inability of the radiographer to properly spread the breast tissue before obtaining the projections, thus the need for improvement on positioning technique which has the greatest influence on the dose received by the glandular tissue and it is also central in producing high quality mammograms. For the medio-lateral projections, 48 (96 %) of the mammograms have all breast tissue shown. 40 (80 %) of the mammograms have the pectoral muscle to the nipple level. 46 (92 %) of the mammograms has symmetrical images of both breast. 18 (36 %) of the mammograms has nipple in profile while only 4 (8%) of the mammograms has the infra-mammary angle clearly demonstrated. Inability to clearly demonstrate the inframmary angle is the criteria with the least score and im-

proper positioning of the breast support plate might be responsible. Overall average score for both cranio-caudal and medio-lateral oblique mammograms are 76 and 61.2 % respectively. Continuous training and education is highly recommended for radiographers in order to meet up with international best practice.

## 5. Conclusion

Local Diagnostic reference level (LDRLs) obtained in the current study 0.52 mGy for cranio-caudal and medio-lateral oblique were lower than the established diagnostic reference level. Image quality was within acceptable percentage. However, LDRLS is an important optimization tool that ensures that unnecessary high or low doses are not used during mammography examination. Optimization process that encompasses both establishment of LDRLs and image quality evaluation is encouraged in our various radio-diagnostic facilities with mammography unit. Radiographic techniques which play essential roles in the production of high-quality mammograms are important in the detection of early breast lesion thus the need to prioritize continuous education and training among personnel.

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