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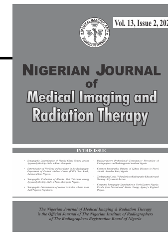

DEVELOPMENT OF INSTITUTIONAL-BASED DIAGNOSTIC REFERENCE LEVELS (IBDRLS) FOR OPTIMIZED RADIATION DOSE IN MAMMOGRAPHY AT UNIVERSITY OF ABUJA TEACHING HOSPITAL, NIGERIA

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ABSTRACT

Introduction: Diagnostic Reference Levels (DRLs) are pivotal in optimizing radiation dose for patient safety during diagnostic and interventional radiological procedures. Mammography is a specialized radiographic examination of the breast, which is essential for early breast cancer detection, employs low-energy X-rays, necessitating precise dose optimization.

Objective: To establish an Institutional-Based Diagnostic Reference Level (IBDRL) for mammography at the University of Abuja Teaching Hospital, Nigeria.

Methodology: Mean glandular dose (MGD) was assessed using thermoluminescent dosimeters (TLDs) and mammography machine-displayed dose values. DRLs were determined as the 75th percentile of the median dose distribution. Statistical methods, including Pearson correlation and paired t-tests, were employed to analyze discrepancies and relationships between the two measurement methods with p value <0.05.

Results: Machine-displayed MGD averaged 2.46 ± 0.80 mGy, significantly higher than the TLD-derived MGD of 0.45 ± 0.47 mGy. DRLs established were 0.50 mGy (TLD) and 3.00 mGy (machine-displayed), aligning with international recommendations. A positive correlation was observed between machine MGD and compressed breast thickness (CBT), whereas TLD-derived MGD showed no significant relationship.

Conclusion: Discrepancies between TLD and machine-displayed doses highlight the importance of consistent dose measurement methods. Both approaches are effective for DRL establishment, promoting patient safety through dose optimization. This study provides a framework for local DRL development, supporting standardized mammography practices and adherence to global standards.

Keywords: Diagnostic Reference Level, Mammography, Mean Glandular Dose, Thermoluminescent Dosimeters, Radiation Dose Optimization.

1.0 INTRODUCTION

Diagnostic Reference Levels (DRLs) represent a pivotal strategy introduced by the International Commission on Radiological Protection (ICRP) to optimize patient protection during diagnostic and interventional radiological procedures. First conceptualized in 1996, the DRL framework has since become an invaluable tool for achieving dose optimization while maintaining diagnostic efficacy [1]. These levels serve as benchmarks for radiation dose metrics, enabling healthcare facilities to assess their practices and determine if imaging quality can be sustained at lower radiation exposures [2]. By highlighting instances where doses exceed typical thresholds, DRLs encourage a review of methods, fostering quality improvement and enhanced patient safety. However, it is crucial to emphasize that DRLs are not dose limits but rather indicative levels, applicable to patient groups or a series of procedures rather than individual cases. Their primary purpose is to signal unusually high radiation doses, prompting an investigation into potential optimizations [1].

Hospitals and imaging centers utilize DRLs as a comparative tool, aligning their dose data with established benchmarks to identify deviations requiring corrective actions. For instance, if routine procedures consistently surpass DRLs, this indicates a need to review equipment functionality or refine procedural techniques to achieve dose optimization [3]. Moreover, the ICRP recommends that national DRLs be determined at the 75th percentile of the distribution of median values for specific examinations within a country. This statistical approach ensures that DRLs are reflective of typical clinical practices while accounting for variations in imaging protocols and patient demographics. DRLs are thus instrumental in addressing excessive radiation exposure, enhancing imaging practices, and maintaining adherence to the standard of care. Local Facility Reference Levels

(FRLs), derived from specific institutional practices, further complement this framework by providing tailored benchmarks for dose optimization within individual facilities [4].

The central objective of DRLs is to prevent unnecessary radiation doses without compromising the diagnostic quality of medical imaging procedures. This balance is essential for effective patient care, as excessive exposure not only increases the risk of radiation-induced complications but may also undermine diagnostic outcomes by failing to optimize imaging protocols [5]. Despite their proven efficacy, significant variability in DRL values has been reported globally, even for the same anatomical region. These discrepancies arise from differences in clinical indications, imaging techniques, and the number of series performed, underscoring the need for locally relevant DRL frameworks to accommodate specific clinical and operational contexts [6].

Mammography, a specialized non-invasive imaging modality, epitomizes the critical interplay between dose optimization and diagnostic quality. Designed to detect, characterize, and evaluate breast abnormalities, mammography is pivotal for early breast cancer detection and diagnosis [7]. It is performed for both symptomatic individuals with suspected breast pathology and asymptomatic women during routine screening. The heightened sensitivity of breast tissue to radiation amplifies the importance of dose optimization in mammography, as both overexposure and underexposure carry significant risks. Excessive radiation can increase the likelihood of radiation-induced malignancies, while inadequate exposure may obscure critical diagnostic details, undermining the detection of pathological changes. Thus, establishing DRLs for mammography is imperative to ensure that clinically diagnostic images are obtained with minimal radiation exposure [7].

Globally, efforts to establish DRLs for mammography have yielded substantial benefits in optimizing patient safety and diagnostic quality. For example, specific DRLs for mammography have been implemented in northeastern Nigeria, reflecting the regional commitment to dose optimization and patient protection [8]. Breast cancer remains a leading cause of morbidity and mortality worldwide, and early detection is critical for improving treatment outcomes and survival rates [9]. Mammography remains the gold standard for breast cancer screening, with advances in technology enhancing its diagnostic accuracy. While film-screen mammography (FSM) offers comparable diagnostic capabilities to digital mammography, the latter demonstrates higher sensitivity, particularly in detecting early-stage cancers [10]. Therefore, the integration of DRLs into mammography practices represents a transformative step in advancing breast cancer diagnostics.

In Nigeria, the burden of breast cancer underscores the urgent need for effective screening and diagnostic interventions. However, the absence of institutional-based DRLs (IBDRLs) at the University of Abuja Teaching Hospital highlights a critical gap in radiological practice. Without standardized benchmarks for mammography doses, significant variations in radiation exposure may compromise patient safety and diagnostic efficacy. Addressing this gap is essential to align the hospital's practices with international standards, optimize imaging protocols, and enhance patient care. Establishing IBDRLs for mammography at this institution will provide a robust framework for dose monitoring and quality assurance, fostering a culture of safety and excellence in radiological practice.

This study aims to establish IBDRLs for mammography at the University of Abuja Teaching Hospital by evaluating current radiation dose levels and comparing them with international standards. The research will involve the determination of mean glandular doses using thermoluminescent dosimeters (TLD), which are recognized as reliable tools for precise dose measurement. Additionally, the study will compare machine-displayed mean glandular doses with values obtained through TLD readings, providing a comprehensive assessment of dose accuracy. By analyzing the relationship between mean glandular dose and compressed breast thickness, the study seeks to identify factors influencing dose variability and establish tailored DRLs reflective of the hospital's unique clinical practices. The findings will serve as a foundation for dose optimization, ensuring that mammography procedures adhere to the highest standards of safety and diagnostic quality.

The establishment of IBDRLs will have far-reaching implications for the University of Abuja Teaching Hospital and beyond. It will provide a reference point for practitioners, regulators, and researchers, facilitating the adoption of best practices and the development of regional and national DRLs. Moreover, the data generated through this study will support regulatory bodies such as the Nigerian Nuclear Regulatory Authority (NNRA) in their efforts to assess and improve mammography systems across the country. As a clinical audit, the research will contribute to continuous quality improvement in mammography services, ensuring that radiation doses remain within acceptable limits while maintaining the diagnostic integrity of imaging procedures. This study represents a critical step in advancing radiological practice in Nigeria by addressing the gap in dose optimization for mammography. The establishment of IBDRLs at the University of Abuja Teaching Hospital will not only enhance the quality and safety of mammography services but also set a precedent for other healthcare institutions across the country. By aligning local practices with international standards, the hospital will contribute to the broader goal of improving breast cancer detection and treatment outcomes, ultimately benefiting patients and healthcare systems alike.

2.0 METHODOLOGY

This study was designed to establish institutional-based Diagnostic Reference Levels (DRLs) for mammography examinations at the University of Abuja Teaching Hospital. The research was conducted in the Radiology Department of the hospital, located in the Federal Capital Territory of Abuja, Nigeria. Data collection spanned from June 2024 to September 2024, utilizing a prospective cross-sectional approach. The study involved adult female patients, aged 40 to 64 years, who were referred for both diagnostic and screening mammography procedures. Exclusion criteria included critically ill patients, women with breast implants, and those who had undergone mammoplasty.

A total of fifty (50) participants were recruited through a convenient sampling technique. Data collection involved obtaining medio-lateral and cranio-caudal projections for each participant. Thermoluminescent dosimeter (TLD) chips, labeled for individual identification, were placed on the upper inner quadrant of the breast before the application of the compression paddle. The mammography machine, operating with automated exposure control (AEC), recorded exposure parameters such as kVp, mAs, anode/filter combination, and breast compression thickness, as well as the average glandular dose (AGD) after each exposure. These parameters, along with the TLD measurements, were meticulously documented for analysis.

TLD chips were processed using a Harshaw 3500 reader at the Center for Energy Research and Training (CERT), Ahmadu Bello University Zaria. Incident air kerma was calculated by subtracting the control TLD readings from the experimental readings. The mean glandular dose (MGD) for both projections was estimated using the Dance et al. (2009) formula, incorporating factors for incident air kerma, breast granularity, and spectra-dependent corrections. Statistical analysis was conducted using SPSS software to compute the total MGD and compare values derived from TLD measurements with machine-displayed AGD values. Paired sample t-tests were employed to assess the significance of differences between the two sets of MGD values.

To evaluate the relationship between compressed breast thickness (CBT) and MGD, Pearson's correlation coefficients were used, and the confidence level was set at < 95% (P<0.05). The Diagnostic Reference Levels for the study were determined as the 75th percentile of the MGD distribution for both projections.
Ethical approval for the study was granted by the ethical committee of the University of Abuja Teaching Hospital. All participants provided informed consent, ensuring adherence to ethical research practices. This comprehensive methodology provides a robust framework for establishing DRLs tailored to the clinical practices and patient demographics of the study facility. Statistical Product and Service Solutions (IBM SPSS Statistics for Windows, Version 26.0.) was used to obtain the 75th (3rd quartile) percentile values of the mean glandular dose for both TLD and machine. The diagnostic reference level for TLD and Machine-displayed values were set at the 75th percentile of the distribution of the mean glandular dose.

3.0 RESULTS

Table 1 Demographic distribution of patients.

Variable	Number of Patients	Percentage (%)
Age (Years)		
40-45	9	30.0
45-55	10	33.3
56-64	11	36.7
Body mass (Kg)		
51-70 *kg*	15	50
71-90 *kg*	11	37
91-110 *kg*	4	13

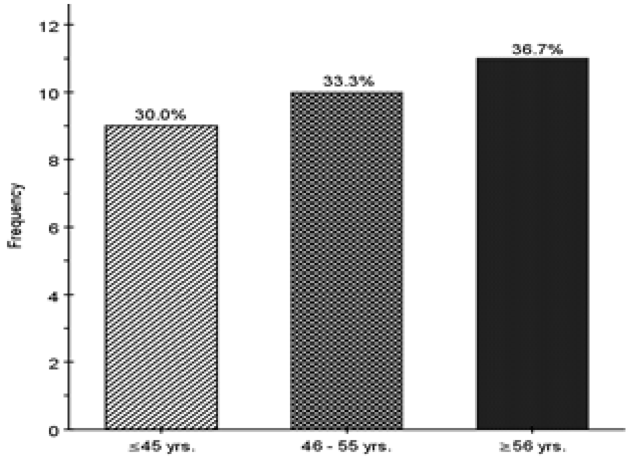

Figure 1: Total Number of Patients According to Age Group

Figure 1: shows that the majority of the patients were within the age group of 56-64 years with 36.7% frequency. The age group of 46-55 years has a frequency of 33.3%. The lowest age group of patients from the sample is 40-45 years with a frequency of 30.0%.

Table 2: Distribution of Age, Compressed Breast Thickness CBT and Incident Air Kerma (K) for Each Patient

Parameters	Age (yrs)	CBT (mm)	K(mGy)
Mean	52.33	50.23	1.74
Minimum	41.00	29.00	0.43
Maximum	67.00	71.00	4.84

The data from Table 2 shows that the age of patients ranged from 40 to 64 years with a mean of 52.33 years. The compressed breast thickness ranged from 29 to 71mm with a mean of 50.23mm. The incident air kerma ranged from 0.43 to 4.84mGy with a mean value of 1.74±1.32mGy.

Table 3 Distribution of Machine -Displayed Mean Glandular Dose Values

Parameters	Compressed Breast Thickness (mm)	Machine Mean Glandular Dose (mGy)
Mean	50.23	2.36
Median	51.00	2.00
Minimum	29.00	1.10
Maximum	71.00	4.83

From Table 3 the machine-displayed mean glandular doses ranged from 1.10 to 4.83mGy. The total mean glandular dose value for the left and right breast is 2.46± 0.80mGy while the compressed breast thickness CBT ranged from 29 to 71mm with a mean of 50.23±9.85mm

Table 3 Distribution of Machine -Displayed Mean Glandular Dose Values

Parameters	Compressed Breast Thickness (mm)	Machine Mean Glandular Dose (mGy)
Mean	50.23	2.36
Median	51.00	2.00
Minimum	29.00	1.10
Maximum	71.00	4.83

From Table 3 the machine-displayed mean glandular doses ranged from 1.10 to 4.83mGy. The total mean glandular dose value for the left and right breast is 2.46 ± 0.80mGy while the compressed breast thickness CBT ranged from 29 to 71mm with a mean of 50.23±9.85mm

Table 4 Distribution of the TLD Mean Glandular Dose Values

Parameters	Compressed Breast Thickness (mm)	Machine Mean Glandular Dose (mGy)
Mean	50.23	0.45
Median	51.0	0.30
Minimum	29.0	0.07
Maximum	71.0	2.46

The data from Table 4.4 shows that the TLD mean glandular ranges from 0.07-2.46mGy and the total mean of the TLD mean glandular doses is 0.45±0.47mGy. The median value of compressed breast thickness CBT is 51.0 while the median value for the TLD mean glandular doses is 0.30mGy.

Table 5 Comparison of Machine-Displayed Dose Values and TLD Dose Values

Parameters	Compressed Breas Thickness (mm)	Machine Mean Glandular Dose (mGy
Mean	2.46	0.45
Median	2.31	0.30
Minimum	1.10	0.07
Maximum	4.83	2.46

From Table 5, the machine-displayed mean glandular dose values range from 1.10-4.83mGy and the TLD mean glandular dose values range from 0.07-2.46mGy. The total mean for the machine-displayed mean glandular dose values is 2.46±0.80mGy while the total mean for the TLD mean glandular dose values is 0.45 ± 0.47mGy.

Table 6: Summary of Paired Sample t-test Comparison for Machine-Displayed MDG and TL MDG

Variable	Mean	SD	t	*P-value*
Machine MDG(Gy)	2.46	0.80	11.30	<0.001
TLD MGD (Gy).	0.45	0.47		

From Table 6, the machine-displayed mean glandular dose value is 2.46 ± 0.80mGy and the TLD mean glandular dose is 0.45±0.47mGy. Table 6 shows that there is a significant difference in the two techniques of data collection with a *P-value* of < 0.001.

Table 7: Pearson Correlation Coefficient (95% CI) between Compressed Breast Thickness CBT and Mean Glandular Dose MGD

Parameters	CBT
	r (95% CI)
Machine MGD (mGy)	0.424 (0.08, 0.68) *
TLD MGD (mGy)	–0.141 (–0.48, 0.23)

***P* <0.05**

From Table 7, the Machine MGD correlation coefficient (r) is 0.424 with a 95% confidence interval (CI) of (0.08.0.68). Machine MGD exhibits a statistically significant positive correlation with $P<0.05$. This suggests that as CBT increases, Machine MGD tends to increase as well.

The TLD MGD correlation coefficient (r) is -0.141 with a 95% confidence interval (CI) of (-0.48, 0.23). The negative coefficient suggests a negative correlation, indicating that there is no significant relationship between CBT and TLD MGD.

4.0 DISCUSSION

The establishment of an institutional-based diagnostic reference level (DRL) for mammography examinations at the University of Abuja Teaching Hospital represents a significant advancement in radiological practice, underscoring the importance of tailored dose optimization strategies. The study revealed a total mean glandular dose (MGD) using thermoluminescent dosimeters (TLD) of 0.45±0.47 mGy, which is well within the European Guidelines for Quality Assurance in Breast Cancer Screening and Diagnosis (EUREF) recommended range of 2.5 mGy and not exceeding 3 mGy. These results align with similar studies, such as those by Dlama et al. [11] and Anesthesia et al. [12], which also utilized TLD measurements. However, they differ from findings by Khadka et al. [13] and Garba et al. [14], who employed machine-generated estimates and automated optimization parameters, respectively, highlighting variations in dose estimation methodologies.

The comparative analysis of MGD values from TLD measurements and machine-displayed outputs revealed a notable disparity. The machine-derived MGD for four views averaged 2.46±0.80 mGy, significantly higher than the TLD-based value of 0.45±0.47 mGy. This difference underscores the distinct nature of the two methodologies. Machine-displayed values reflect theoretical or calculated doses, while TLD measurements capture real-world physical doses, potentially influenced by factors such as TLD chip placement, dosimeter calibration, and sensitivity. These findings are consistent with previous research, including studies by Garba et al. [14] and Anesthesia et al. [12], which noted significant differences in MGD values based on the method used. The potential underestimation of TLD-derived MGD due to its surface dose measurement approach and reliance on conversion models further emphasizes the need for cautious interpretation of results when using different methodologies.

Correlation analysis between MGD and compressed breast thickness (CBT) revealed contrasting relationships depending on the measurement approach. Machine-derived MGD exhibited a statistically significant positive correlation ($r = 0.424$, $p < 0.05$), indicating that MGD tends to increase with CBT. This trend aligns with studies by Nassar et al. [15] and Khadka et al. [13], which reported similar findings. Conversely, TLD-derived MGD demonstrated a weak negative correlation ($r = -0.141$) with CBT, suggesting no significant relationship. These divergent results may stem from differences in sensitivity to dose variations and the specific conditions under which TLD measurements are conducted, as previously observed by Dlama et al. [11].

The DRL values derived from the study further illuminate the implications of measurement methodology. The DRL calculated using TLD measurements was 0.50 mGy, lower than those reported by Abdulwahid et al. [16], Garba et al. [14], and Dlama et al. [11]. This difference may reflect variations in population size, measurement techniques, and institutional emphasis on dose reduction while maintaining acceptable image quality. Conversely, the machine-derived DRL was 3.0 mGy, aligning with established benchmarks and within the recommended range. The disparity between TLD and machine-derived DRLs underscores the influence of methodological choices on reference level determination and emphasizes the need for context-specific calibration and interpretation. The findings of this study not only validate the feasibility of establishing DRLs within the University of Abuja Teaching Hospital but also highlight the importance of methodological considerations in dose estimation. The observed differences between TLD and machine-derived values underscore the need for careful selection of measurement tools and techniques to ensure accuracy and consistency. By prioritizing dose optimization alongside diagnostic efficacy, the institution sets a benchmark for quality assurance in mammography, with implications for broader adoption in similar healthcare settings. Future research should aim to standardize methodologies and explore the interplay between dose, image quality, and patient outcomes to further enhance the safety and effectiveness of mammography practices.

This research paper investigates the establishment of an institutional-based Diagnostic Reference Level (DRL) for mammography at the University of Abuja Teaching Hospital in Nigeria, emphasizing the need for standardized DRLs to minimize radiation risks and maintain diagnostic quality. The study used thermoluminescent dosimeter chips and machine-displayed values to measure mean glandular dose (MGD) and compressed breast thickness, with significant discrepancies noted between the two measurement methods; however, both are within the recommended level by EUREF. The determined DRLs for TLD and machine-displayed MGDs are 0.50 mGy and 3.00 mGy, respectively. The study underscores the importance of optimizing radiation doses for patient safety and aligns with global research on DRL establishment and the critical role of dose monitoring and optimization in mammography.

5.0 CONCLUSION

The study underscores the importance of establishing diagnostic reference levels (DRLs) for mammography to ensure patient safety and dose optimization. By comparing thermoluminescent dosimeter (TLD) measurements with machine-displayed doses, significant discrepancies were observed, though both methods were deemed suitable for DRL establishment. The research demonstrated a positive correlation between mean glandular dose (MGD) and compressed breast thickness (CBT), with machine-displayed MGD values notably higher than TLD measurements. Institutional DRLs provide a crucial benchmark for quality assurance, aligning with international standards, and the findings advocate for continuous updates to DRL values. This research lays the groundwork for setting national and regional DRLs to promote standardized mammography practices.

6.0 RECOMMENDATIONS:

1. There is an urgent and cogent need to conduct routine calibration and quality control of mammography equipment by medical physicists.
2. Verify machine-reported dose parameters for accuracy.
3. Train radiologists, radiographers, and medical physicists on the significance of DRLs, accurate dose measurement, and imaging optimization following the ALARA principle

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Conflict of Interest: Authors declare that there is no conflict of Interest.

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