LOCAL DIAGNOSTIC REFERENCE LEVELS FOR DIGITAL MAMMOGRAPHY: TWO HOSPITALS STUDY IN NORTHWEST, NIGERIA

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Abstract

The study established local DRLs for digital mammography for the purpose of in house dose optimisation. The study had a total of 240 women that presented for mammography at the two tertiary institutions in northwest Nigeria. Patient demographic information including compressed breast thickness and mean glandular dose (MGD) were recorded. Local DRLs based on MGD and CBT were established at the 75th percentile (CC: 1.50 mGy; 57 mm; MLO: 1.60 mGy; 63 mm) and 95th percentile (CC: 3.74 mGy; 69 mm; MLO: 3.61 mGy; 76 mm). The MGD based on manual exposure was significantly (p<0.005) higher compared to the automatic optimisation parameter (AOP) mode which suggests the need to continuously adhere to the use of AOP mode for the purpose of in house dose optimisation.

KEYWORDS: optimisation; mean glandular dose; compressed breast thickness

1. Introduction

Mammography is the most reliable method which is frequently being used to detect breast cancer before the appearance of clinical symptoms (1). Breast cancer is the most common cancer in women globally, and in Nigeria (2). The incidence rate of breast cancer is consistently increasing 1-2 percent annually. Basically, there are two categories of women that undergo mammography: symptomatic women in the clinic, and asymptomatic women in the breast screening programmes (3). Screening mammography invites healthy women for an X-ray examination of the breast, with the aim of early detection of breast cancer (4). Whilst, symptomatic mammography is an X-ray examination of the breast of a patient with signs or symptoms of breast disease (5).

Although mammographic examination is associated with a low dose to the breast tissue, the use of ionising radiation implies the risk of inducing breast cancer (6). Therefore, the need to optimise the use of ionising radiation in mammography is highly recommended. One of the ways for performing dose optimisation, is through regular patient dose measurement and monitoring (7), and several dose indices such as mean glandular dose (MGD) were recommended for reporting dose in mammography (8).

Glandular tissue in the female breast is regarded as the most radiosensitive organ and therefore, mean glandular dose (MGD) of the breast tissue is considered to be the most important quantity to estimate the risk of radiation-induced carcinogenesis from mammography (6). MGD is defined as the average absorbed dose in the glandular tissue (excluding skin) in a uniformly compressed breast (9). It is important to highlight that MGD is always an estimate, as it is not possible to measure the absorbed dose by the glandular tissue directly. Also, the differences in density distribution of the glandular tissue depend on the thickness of the breast and age of women(4).

Even though, there are several local dose surveys on mammography examination carried out in Nigeria (7,10,11), however, none exist in the northwest region. Therefore, this is the first dose survey conducted in two hospitals to determine MGD for women that had mammography examination using digital mammography machines, and also establish local DRLs for the purpose of in house dose optimisation.

2. Materials and methods

This was a retrospective and cross-sectional study carried out at the Radiology department of two tertiary hospitals located in the northwest region of Nigeria following ethical approval from the two

institutions research and ethics boards. The institutions were selected based on careful assessment of the equipment, personnel and patient turnout. The mammographic examinations were performed in both hospitals using SENOGRAPHE ESSENTIAL GE mammography machines which are full-field digital equipment. In hospital A the equipment was manufactured by GE in Hualun Beijing, China in 2010, and installed in 2014. Whilst in hospital B the equipment was manufactured by GE in Hungary KFT, Budapest in 2013 and stalled in 2018. Both machines have maximum of 49 kV and 500 mAs, with a record indicating frequent quality control (QC) related to the tube warm up performed before start of the day work. Quality control related to dose output or half value layer was never performed either at the stage of installation or being performed as part of routine maintenance tests due to lack of a qualified medical physicist and equipment required for QC. However, service engineers employed by the GE vendor visit regularly to check for dust and electronic component to ensure the machine works satisfactory. In addition, the engineers check for image quality at every visit using an image quality phantom to ensure image quality is within the acceptable limit and free of artefacts. The data was collected and analysed following the ICRP recommendation for establishing DRL in mammography (12). In the two hospitals, record of all patients that had mammography on account of diagnosis or screening was assessed. Based on the record available, routine views for mammography in the two hospitals were cranio-caudal (CC) and medio-lateral oblique (MLO) and patients included in this study had both views for each breast. Dose data collected for each view was as follows: CBT and MGD. CBT and MGD for each breast and view were recorded as displayed on the mammography machine. However, there was no accuracy test conducted on MGD to determine the deviation from the calculated value of MGD. Mammography machine manufacturers used different calculation methods for MGD. In this study the equipment are of GE type which incorporated the Wu calculation method. In addition, exposure parameters such as kV, mAs, and exposure mode were also recorded including patient demographic information such as the age of patient. AOP which is the GE specific term for automatic exposure control (AEC) was the default exposure setting in the two mammography units. However, in hospital A, a manual exposure mode was used due to a faulty AOP mode. A standard (STD) AOP mode setting was used in the two machines. The data was analysed using a statistical package for social sciences (SPSS) version (16). Both descriptive and inferential statistics were employed. Local DRLs for in house optimisation purposes were established at the 75^{th} and 95^{th} percentiles and compared with the values established in the literature. A p value of ≤ 0.05 was considered as a level of significance at 95% confidence interval.

3. Results

Data of 240 women that had mammography examination was collected from the two hospitals visited. The age of women included in the study ranges from 28–79 years with mean ± SD of 48 ± 9 years. A significant ($p \leq 0.05$) correlation ($r = 0.51$) was noted between the patient age and MGD. The machines were operated in AOP mode in 80.83% of the cases, and 19.20% of the cases were performed using the manual exposure mode. MGD distributions for both the manual and AOP modes from the two hospitals are presented in Figure 1 using boxplots. Exposure parameters which include kV and mAs were recorded for each of the exposure modes and hospitals as presented in Table 1. CBT and MGD for CC and MLO, and for both the manual and AOP modes are presented in Table 2. Table 3 compares MGD between studies. DRLs for this study was established at the 75^{th} and 95^{th} as presented in Table 4.

4. Discussion

Radiation exposures have been established as one of the factors responsible for increasing the risks of breast cancers, especially after multiple exposures in the chest area and radiosensitive glandular tissues. A lot of studies have examined glandular doses in order to quantify and predict the amount of increase in cancer risks (2,5,6). The present study examined the mean glandular dose received by patients that underwent mammography examination for a period of 14 months at two tertiary hospitals in the northwest region of Nigeria. The machines used were full field digital mammography (FFDM) machines that have two basic exposure modes namely: the AOP and manual exposure modes.

The AOP is an automatic beam quality selection mode with an automatic exposure control (AEC), which automatically selects kVp, milliampere-seconds (mAs), target material and filter according to

the breast thickness and composition (24). Meanwhile, in the manual exposure mode, the settings are selected by the radiographer based on assessment of the breast thickness, and composition and/or image quality required. Like the AEC in screen-film mammography, AOP also terminates exposure when a pre-determined signal is detected by the sensor (25). In the two hospitals visited, AOP was the default exposure setting used. However, in hospital A, the AOP mode became faulty which resulted in image quality degradation. Whilst waiting for equipment to be repaired, manual selection of the exposure parameters was employed for optimal image quality. The selection of the scan parameters was arbitrarily performed by the radiographers as no reference table provided by the vendors was available where preset scan parameters are a function of the compressed breast thickness.

The MGD reported in this study is based on the recorded dose from the DICOM readout header. The accuracy of the recorded dose could not be established due to lack of QC equipment and medical physicists that could conduct the test. According to Suleiman et al. (4), the recorded dose from the DICOM readout header, GE had the highest bias, overestimated Wu calculation method by 0.2 mGy. Therefore, dose measurement based on MGD is an estimate due to errors posed by the calculation method which would have an impact on the overall reported doses. MGD represents dose based on the breast model rather than the dose to the breast tissue (4). Therefore based on MGD, it is not possible to measure absorbed dose by the glandular tissue directly. Also, the differences in density distribution of the glandular tissue which also depend on the thickness of the breast as well as age of women could not be measured by the displayed MGD values as reported by Suleiman et al. (4).

The mean age of women included in this study was 48 ±9 years which coincides with the age of menopause during which significant changes in composition of the breast are known to occur (26). The mean age compares well to the age (51 years) reported in studies conducted by Jamal et al., (27) and Ogundare et al., (7) in Malaysia and Nigeria respectively..

The dose received with the AOP mode was averaged as 1.17 mGy for CC, and 1.26 mGy for MLO projections. The ~2% difference in MGD between the CC and MLO projections agreed with findings of most literature reviewed which showed that the CC projection has lower MGD than MLO (14,16,19,28). The observed difference in MGD between the CC and MLO projections could be as a result of higher value of CBT in MLO (15,18,29). The mean glandular dose for the manual mode was 3.15 mGy, and 2.89 mGy for CC and MLO projections respectively. This shows that MGD in the manual exposure mode is 2-fold higher compared to MGD in the AOP mode. The difference in MGD between the two exposure modes was statistically significant ($p<0.01$). The higher MGD is related to the manual exposure mode where a higher mAs was used (Table 1). Therefore, there is a need to investigate the reason for using higher mAs in the manual exposure mode so as to determine the root cause as there could be legitimate reasons for using higher mAs. Inconsistency in the selection of exposure parameters as demonstrated in the dose distribution for the manual mode was noted (Figure 1). Furthermore, MGD for CC was found to be higher than that of MLO in the manual mode. This finding is in contrast to most of the results available in the literature (17,22,27). Though not investigated, however there is a possibility of those studies using the automatic exposure mode as manual selection of the exposure parameters could be characterized with higher doses and lack of consistency in exposure factors selection. Using the manual exposure mode, Radiographers could be tempted to achieve higher image quality which means higher exposure factors and higher doses. In addition, the use of relatively small study sample and the larger variation in the breast thicknesses of the women could also be possible contributor to higher MGD for CC view. More scrutiny on the equipment and examination techniques employed by the radiographers could be needed to definitively establish the root cause of higher MGD in the manual parameter selection in this study.

Dose comparison in terms of MGD was performed between this study and similar studies published in the literature (Table 3). MGD in this study was based on the Wu calculation method and study conducted by Tsai et al. (28) has shown that MGD based on the Dance calculation method could be 9-21% higher than the MGD calculated using the Wu method. The MGD values in the present study were found to align with the published values in studies conducted in Nigeria by Ogundare et al. (7) and Kenya by Wambani et al. (18) where the Wu calculation method was used to estimate MGD

(Table 3). Similarly, MGD of this study was compared with values reported in studies conducted in Nigeria by Chijoke et al. (11) and Ethiopia by Dellie et al. (21) where the Dance calculation method was employed. MGDs of the compared studies were higher and variation up to 40% was obtained. The reason for lower MGD in this study could be due to the fact that digital mammography systems which allow for dose optimisation due to post processing capability were used, however in the two studies compared a film screen system was used where no post processing could be performed.

The MGD values of this study were compared with values reported in studies conducted in Spain and Qatar where digital mammography machine was used and the Dance calculation method was employed as presented in Table 3. MGD of the present study was found to be lower than the compared values. The difference in MGD between studies was 16% which was within the 9-21% expected variation as reported by Tsai et al (28). However, The MGD value in this study compared higher than the values reported in studies conducted in Malta and Italy where the Dance calculation method was reported. MGD difference between this study and the studies conducted in Malta and Italy was 33% which was higher than the 9-21% expected variation (28). One of the reasons for higher MGD in this study despite the use of Wu calculation method could be due to incorporation of dose from the manual selection of parameters which is associated with higher exposure. This indicates the need to review protocol especially the manual exposure selection in the present study for the purpose of optimisation. Further, there is a need for the harmonization of protocol and methods of dose calculation in order to minimise dose variation between studies which promotes radiation dose comparison.

Previous studies (6,8,9,27,29) have reported MGD as a function of CBT, which means that MGD increases with an increase in CBT. These findings agree with the finding of the present study as presented in Figure 2 where MGD increases with CBT especially for the AOP mode, whereas for the manual selection of the exposure parameters, the relationship between CBT and MGD is in contrast with the literature findings perhaps due to inconsistency in exposure parameter selection by the radiographers.

DRLs have shown to be an effective method for optimisation of exposure in diagnostic imaging. DRLs ensure dose variation for the same examination across centres or hospitals is minimised. A 75^{th} percentile used in general radiography identified 25^{th} of the distribution that are giving higher exposure and encourage to optimise their protocol (12). In mammography a 95^{th} percentile is used due to tight dose variation (4). In this study, DRLs have been established at both the 75^{th} and 95^{th} as presented in Table 4 to promote dose comparison between studies. The established DRLs align with values established in Australia by Suleiman and Greece by Lekatou et al. (23) where digital mammography systems were used.

5. CONCLUSION

The present study has established local DRLs for the digital mammography systems at the 75^{th} and 95^{th} percentiles which compared well with the values established in the literature. The observed MGD for the manual mode was found to be significantly higher compared to the AOP mode. This suggests the need to continuously adhere to the use of AOP mode due to its lower dose advantage for the purpose of dose optimisation. However, manual selection of parameters could be employed where there are legitimate indications, and should be based on preset tables as a function of compressed breast thickness.

5.1 RECOMMENDATIONS

The AOP mode should be adopted rather than the manual exposure mode due to its observed lower MGD and ensuring adequate and consistent image quality in our study. There is also a need for standardized method and protocol for setting DRLs so that a more accurate comparison can be made. Image quality study in further recommended to aid dose optimisation. Finally, more studies in other regions of Nigeria are encouraged to come up with local DRL, which would facilitate the establishment of regional or national DRLs

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5.3 CONSENT

Not applicable

5.4 SOURCE OF FUNDING

None

5.5 CONFLICT OF INTRESTS

None Declared

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Figure 1: dose data distribution for both manual and AOP modes

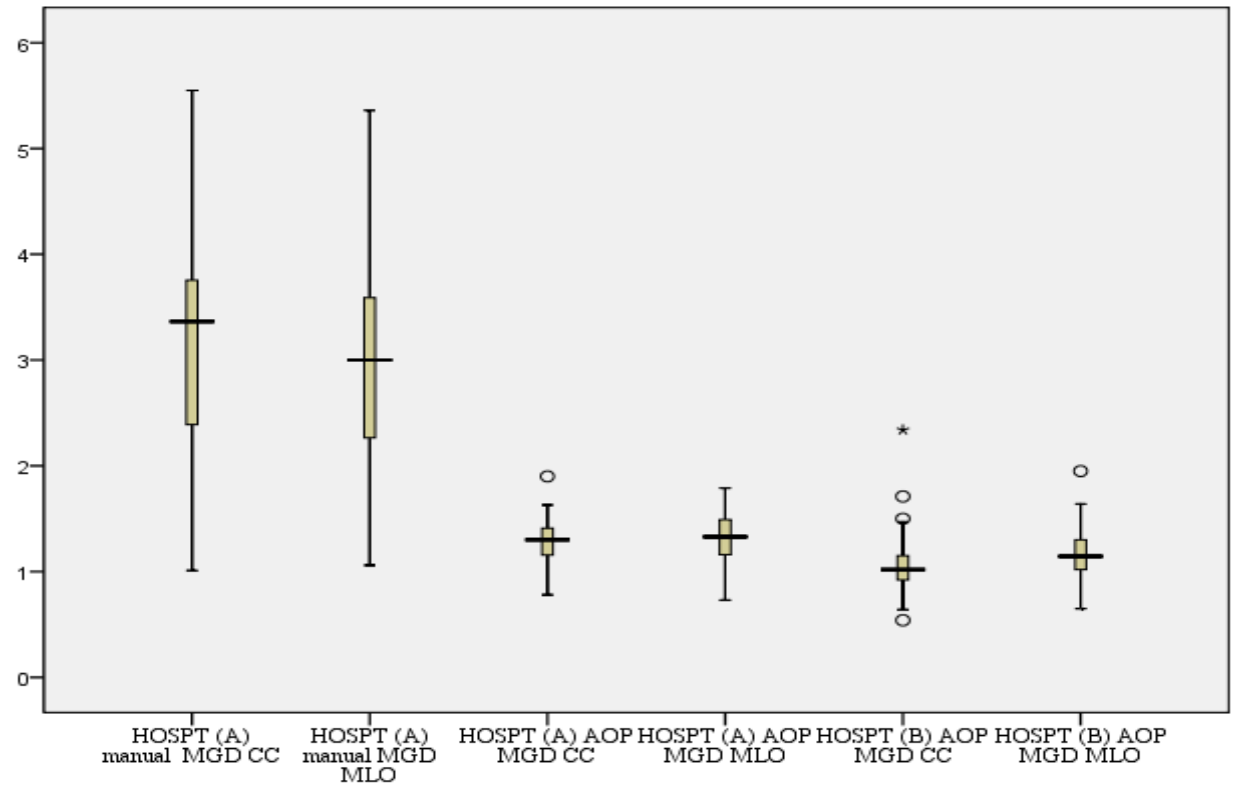
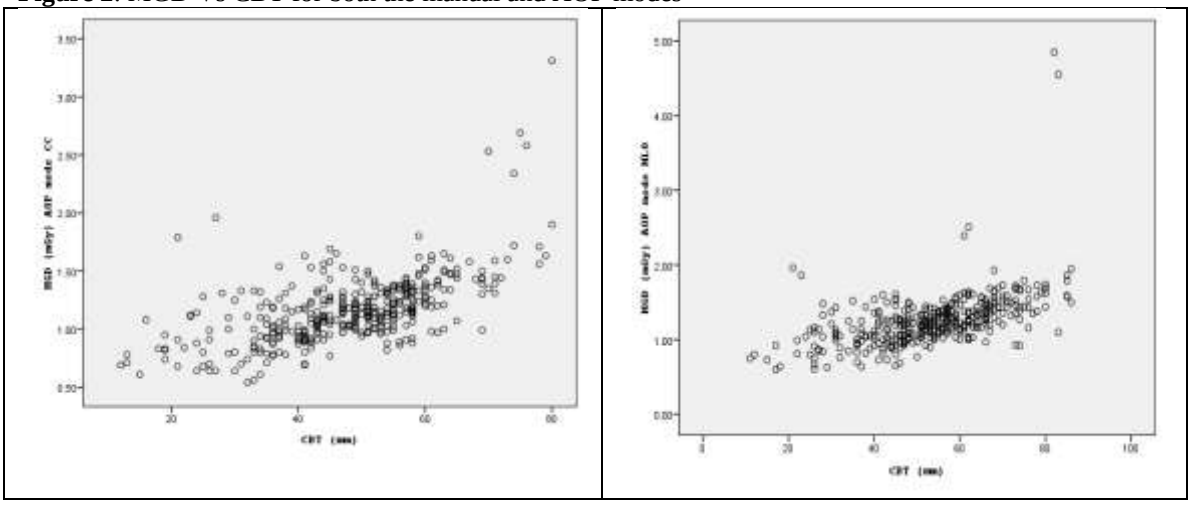


Figure 2: MGD Vs CBT for both the manual and AOP modes



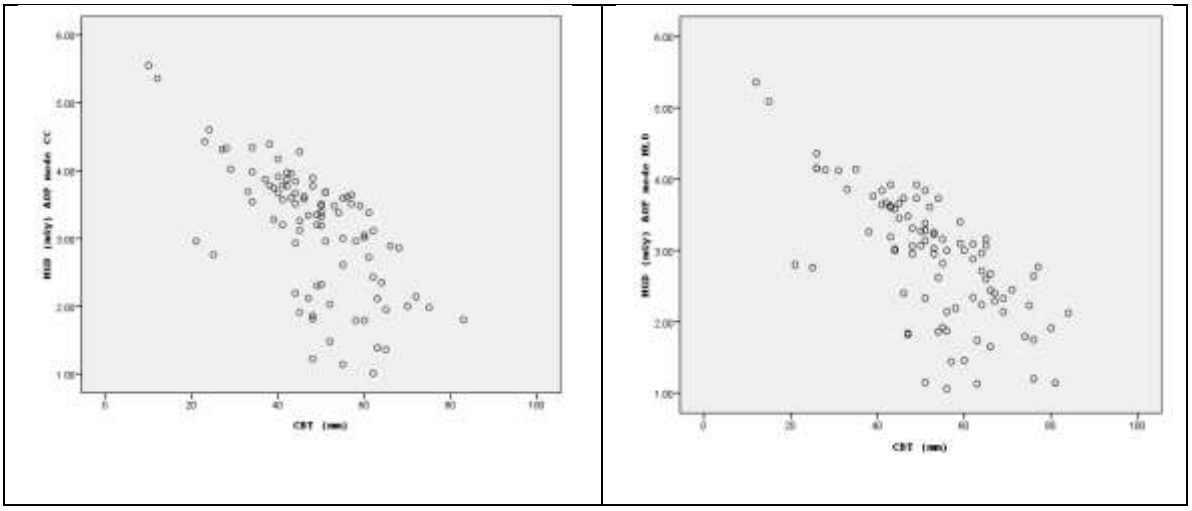


Table 1: Descriptive statistics of exposure parameters for both AOP and manual modes

Hospital	Exposure mode	View	kV (Range)	mAs: Mean (Range)
Hospital A	AOP	CC	(26 - 31)	54.64 ± 15.10 (25 - 177)
		MLO	(26 - 31)	59.53 ± 23.12 (26 - 322)
	MANUAL	CC	(26 - 29)	164.00 ±33.30 (63 - 180)
		MLO	(26 - 29)	164.00 ±33.30 (63 - 180)
Hospital B	AOP	CC	(26 -31)	43.79 ±19.97 (22 - 224)
		MLO	(26 - 31)	49.53 ± 24.94 (23 - 335)
Combined data (A and B)	AOP	CC	(26 -31)	49.06 ±18.56 (22 - 224)
		MLO	(26 - 31)	54.37 ± 24.56 (23 - 335)
Combined data (A and B)	AOP and Manual	CC	(26 -31)	71.04 ± 50.57 (22 - 224)
		MLO	(26 -31)	75.39 ± 50.63 (22 - 335)

Table 2: Descriptive analysis of CBT and MGD for CC and MLO projections

Hospital	Exposure mode	View	CBT (mm): Mean (Range	MGD (mGy): Mean (Range)
Hospital A	AOP	CC	48.61 ± 13.53 (12 – 81)	1.29 ± 0.26 (0.69 – 2.69)
		MLO	51.43 ± 14.96 (11 - 85)	1.37 ± 0.34 (0.73 - 4.55)
	MANUAL	CC	48.09 ± 13.09 (10 – 83)	3.15 ± 0.93 (1.01 – 5.55)
		MLO	52.84 ± 14.72 (12 - 84)	2.90 ± 0.89 (1.06 – 5.36)
Hospital B	AOP	CC	47.58 ± 11.89 (15 - 80)	1.10 ± 0.29 (0.54 - 3.34)
		MLO	55.32 ± 13.78 (17 – 86)	1.16 ± 0.36 (0.60 – 4.85)
Combined data (A and B)	AOP	CC	48.08 ± 12.70 (12 – 80)	1.17 ± 0.30 (0.53 – 3.31)
		MLO	53.43 ± 14.48 (11 – 86)	1.26 ± 0.36 (0.60 – 4.85)
Combined data (A and B)	AOP and manual	CC	48.08 ± 12.06 (10-83)	1.55 ± 0.92 (0.54 - 5.55)
		MLO	53.32 ± 14.50 (11 -86)	1.57 ± 0.82 (0.60 – 5.36)

Table 3: DRLs comparison based on MGD between studies

Study	No. of patients or views	Method	Calculation factor/protocol	Mean CBT (cm)	MGD (mGy)
Italy (13)	800	Measured[a]	Dance/EP	CC; 5.57	1.15
Turkey (6)	641	Calculated	Boone/EP	CC; 5.27	1.82
				MLO; 5.60	1.94
Spain (14)	20137	Calculated	Dance/EP	CC; 5.2	1.80
				MLO; 5.2	1.95
Qatar (15)	3280	Measured[a]	Dance/EP		CC; 1.84 MLO;1.8
Malta (16)	759	Estimated	Dance/EP	CC; 5.38	1.06
				MLO; 6.34	1.07
****Korea** (17)	46	Measured[a]	Wu/ACR	CC; 3.60	1.77 mSv
				MLO: 3.90	1.88 mSv
***Kenya** (18)	1252	Estimated	Wu/EP	CC; 4.0	1.14
				MLO; 4.0	1.44
***Iran** (19)	230	Measured[a]	Dance	CC; 4.18	1.18
				MLO; 5.03	1.39
***Norway** (20)	1183	Measured[a]	Dance/EP	CC; 5.11	1.33
				MLO; 5.21	1.45
***Ethiopia** (21)	368	Calculated	Dance/EP	CC; 4.24	2.56
				MLO; 4.64	2.57
***Nigeria** (7)	40	Measured[a]	Wu	CC; 3.38	0.31
				MLO; 4.85	1.43
***Nigeria** (11)	427	Measured[a]	Dance/EP	CC; 5.2	2.12
				MLO; 5.2	2.63
***Greece** (22)	250	Calculated	Dance/EP	CC; 4.2	1.21
				MLO; 4.2	1.50
Present study	140	Estimated	Wu/EP	CC; 4.8	1.55
				MLO; 5.3	1.57

** MGD presented in mSv

* Studies carried out using film screen mammography system.

[a] ESD/ESE/ESAK measured using a TLD chips or Ionization chambers.

Table 4: DRLs in terms of MGD and CBT at 75th and 95th percentiles

Variable	This study DRL	This study DRL	Australia DRL Suleiman et al. (4)	Greece DRL Lekatou et al. (23)	
Percentile	**75th**	**95th**	**75th**	**75th**	**95th**
MGD CC	1.50	3.74	2.06	1.44	1.77
CBT CC	57.00	69.00			
MGD MLO	1.60	3.61		1.48	1.78
CBT MLO	63.00	76.00			