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Evaluation of Mean Glandular Dose from Digital Mammography Exams at Qatar and Compared with International Guidelines Levels

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The primary objective of this study was to measure the mean glandular dose (MGD) from craniocaudal (CC) and mediolateral oblique (MLO) views from mammography patients in Hamad Medical Corporation (HMC) in the state of Qatar and to compare them with the international guidelines levels as well as to establish Dose Reference Level (DRL) for the country by applying the quality control (QC) protocol for the Digital mammography units and to reduce the patient dose and improve the image quality.

All patients data was taken from two Selenia digital mammography units for 18 months period. Quality control was implemented for the two mammography machines and corrective actions have been done for the image quality evaluation with rejected film analysis.

The total number of collected patient data was 4085 mammography exams which considered as around 93% of the overall mammography procedures done in Qatar during that period.

Based on the IAEA selection criteria of breast thickness between 2-7 *cm* and kV machine value

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from 26 to 33 kV, only 3280 mammography procedures satisfies the above criteria and are analysed accordingly, National Centre for Cancer Care & Research (NCCCR) 949 and Hamad General Hospital (HGH) 2331 exposures.
The present study revealed that there were significant differences between the MGD values for the CC and MLO views (p <0.006).
Referring to the limiting dose values in the European guidelines, the results from the two mammography units showed that 94.5% and 99.7% of the mean glandular doses are acceptable from NCCCR and HGH respectively. Due to compression devise error in the NCCCR mammography machine, the MGD for some patients became more than the acceptable values especially at small breast thickness values (0-3 *cm*) which it seems 0% in the acceptable range.

Keywords: Compressed breast thickness; entrance surface air kerma; mammography; and mean glandular dose.

1. INTRODUCTION

An increased awareness of the benefits of early detection of breast cancer has caused a resurgence of the use of mammography. This has resulted in a large increase in the number of installed units and also in the number of manufacturers marketing equipment. Mammography is one of the most technically exacting radiographic procedures.

A small change in technique or processing factors can have a significant effect on image quality and radiation dose delivered to the breast. In order to produce mammograms at the lowest doses consistent with high diagnostic sensitivity and specificity, it is necessary that careful consideration be given to the selection of equipment, patient positioning, imaging techniques, and the establishment of an effective quality control program [1].

X-ray equipment, especially target-filter combination, recording systems, compression of breast and structural characteristics of breast can affect the MGD. The current guidance for the mammography adopts 3mGy as a dose guidance level for standard breast is recommended by the International Atomic Energy Agency (IAEA) [2]. The exposure reduction depends on the technique of radiological technologists. It is needed for them to optimize affecting factors [3].

The main objective of this study is to evaluate the MGD in mammography in the state of Qatar with the main purpose of establishing Dose Reference Level (DRL) for the country by applying the quality control (QC) protocol for the Digital mammography units which will reduce the patient dose and improve the image quality.

Cancer occurs due to multiple factors. One of them is radioactivity. While breast cancer can be diagnosed earlier by the help of mammography [4,5].

2. MATERIALS AND METHODS

In this study a survey of patient's data was performed from two Selenia digital mammography units. The first machine used for general diagnostic purposes was in the main hospital HGH and the second one was used for detecting the malignant cells in the NCCCR. Both machines have the same targets and filters (W/RH). The protocols in both hospitals are one CC and one (MLO projections. The patients were classified according to their compressed breast thickness into three groups: Fatty breast range from 5-7 *cm*, medium breast from 3 to 5 *cm* and dense breast from 2 to 3 *cm*. The reason for choosing these depths was because the existing different protocols covered only specific depths. For example, the American College of Radiology (ACR) chose 4.2 cm; in the United Kingdom they used 4.5 cm and in Australia they used a 5 cm depth [6].

The method for estimating the MGD to the patient breast consisted of collecting the data for each exposure with an indication of the tube voltage (kVp), mAs and target/filter combination. Thereafter, breast entrance skin exposure (K) was measured by using the ionization chamber placed in the x-ray field includes the Automatic Exposure Control (AEC) with different PMMA thicknesses presented in Table 1.

Table 1. The relation between the measured output/mAs and PMMA thicknesses in cm using AEC

PMMA thickness (*cm*)	kV	mAs	anode/filter	Measured mGy	Correction factor	Output (mGy/mAs)
1.8	25	040	W/RH	1.000	1	0.0250
3.6	27	085	W/RH	2.528	1	0.0297
4.5	28	120	W/RH	3.991	1	0.0333
5.0	29	123	W/RH	4.600	1	0.0374
6.0	30	200	W/RH	8.250	1	0.0413

Barracuda set (oRTIgo QA Software for Barracuda PMX-III PMX-I QA-kit, Version 5.1 A) coupled with the new Multi-purpose Detector (MPD) was used for the measurements. The sensitive detector area on the MPD, including kVp and dose detector, is only 3x21.1 mm (0.11″ x 0.83″). The R100B is a dose detector for the Barbuda; it is specially designed for low dose rate measurements. R100B is a solid state detector with a metal housing which makes it very durable; it does not need correction for temperature or pressure and needs no bias voltage. The measured dose (mGy) was converted to MGD according to the European guidelines and compared with the IAEA and European guidance values [2,4].

2.1 Statistical Analysis

Descriptive statistics such as, standard deviation, p-value and percentage were used to analyze the data using the Microsoft excel 2010 functions.

2.2 Quality Control

Quality control for mammography machines has been assessed including output reproducibility mGy, kVp accuracy & reproducibility, AEC performance linearity, Mean Glandular Dose mGy, HVL (mm/Al), Breast thickness indicator as well as compression test. QC of mammography systems was evaluated according to the Selenia manual recommendations and AAPM report No 29 [1,7,8]. Beam quality assessments by measuring the HVL are presented in Table 2. As shown in Table 2 the HVL ranges from 0.527 to 0.612 mmAl through the tube voltage range from 26-34 kVp and output per unit mAs ranged between 0.0250-0.00478 uGy/mAs. The equation used to calculate the MGD was:

$$MGD = \mathrm{K\,(mGy)} \times \text{conversion factors},$$
$$\text{conversion factors} = \mathrm{g} \times \mathrm{c} \times \mathrm{s}$$

Where:

K: is the entrance surface air Kerma and converts incident air Kerma to mean glandular dose

g : factor corresponds to a granularity of 50% [9].

c : factor corrects for difference in compression of typical breasts from 50% granularity

s : factor corrects for difference due to the choice of X-ray spectrum

Table 2. The HVL at the specified nominal tube voltages are shown

Nominal tube voltage (kVp)	HVL (mm Al)
26	0.527
27	0.541
28	0.555
29	0.567
30	0.579
31	0.589
32	0.598
33	0.610
34	0.612

3. RESULTS AND DISCUSSION

The age of the examined patients varies from 40 to 80 years old, but most of the patients in the age group of 45–59 had 85.88% from all exposures, which is considered to be the most important age of enhanced risk for breast cancer incidence [10,11]. MGD was calculated according to the method provided in EUREF European guidelines (4) presented in Table 3. The above Table presents the recommended achievable and limiting dose values in the European guidelines for the same PMMA thickness values are 0.6, 1, 1.6, 2, 2.4, 3.6, 5.1 mGy and 1, 1.5, 2, 2.5, 3, 4.5, 6.5 mGy respectively for 2, 3, 4, 4.5, 5, 6 and 7 *cm* of PMMA [9].

The patients classified according to their compressed breast thickness into three groups, fatty breast range from 5-7 *cm*, and medium breast from 3 to 5 *cm* and dense breast from 2 to 3 *cm*. Most of the patients fall in the fatty category presented in Table 4 and Fig. 1.

Fig. 1 showed that 70.15% classified in the fatty group (5-7 *cm*), 28.93% of the exposures in the medium group and only 0.92% in the dense group. Table 4 mentioned that, all MGD values in the fatty group were acceptable but 52 out of 949 MGDs values (Medium group) were more than the European guidance values and 8 out of 30 (dense group) were also more than the European guidance values.

Results of the measured Entrance Surface Air Kerma ESAK and calculated MGD were summarized in Table 5.

As illustrated in Table 5 there were significant differences between the MGD values for the CC and MLO views (p <0.006).The average MGD of 1.885 mGy and 1.84 mGy for the MLO and CC views respectively in this study was found to be lower than the recommended guidance value of 3.0 mGy and compared to some other published values [12-19]. Heggie has reported that if the survey data was reanalyzed assuming a 50:50 adipose: glandular composition, the average MGD per film was reduced from 2.3 mGy to 2.1 mGy, a 5.2%reduction. Similarly, Klein reported that the actual breast composition may cause a variation as much as 15% [11,20,21].

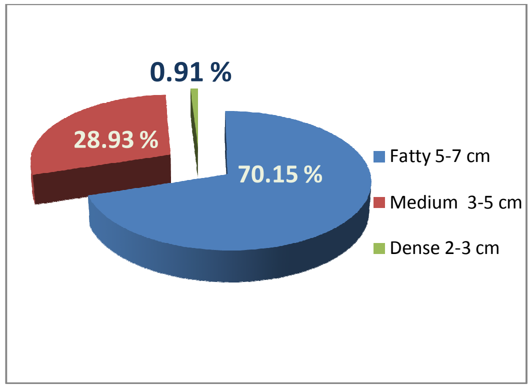

Fig. 1. Illustrate the Classification of the patient according to the CBT in cm

Table 3. European guidance: A maximum average glandular dose is set per PMMA thickness

Thickness of PMMA *cm*	Equivalent breast thickness *cm*	Maximum average glandular dose to equivalent breasts	
		Acceptable level mGy	Achievable level mGy
2.0	2.1	1.0	0.6
3.0	3.2	1.5	1.0
4.0	4.5	2.0	1.6
4.5	5.3	2.5	2.0
5.0	6.0	3.0	2.4
6.0	7.5	4.5	3.6
7.0	9.0	6.5	5.1

Table 4. Result of comparison between calculated mean glandular doses MGD and European guidance values by patients' groups

	Breast thickness European guidance values	Fatty 5-7 *cm* < 6.5 mGy	Medium 3-5 *cm* < 3 mGy	Dense 2-3 *cm* < 1.5 mGy
NCCCR	Patient No	746	198	5
	Out of the limit	0	47	5
HGH	Patient No	1555	751	25
	Out of the limit	0	5	3

Table 5. Mean +/-SD and range of measured ESAK and calculated MGD

Projection	ESAK (mGy)		MGD (mGy)	
	Mean ±SD	Range	Mean ±SD	Range
NCCCR- CC	6.67±1.82	3.19 – 14.50	1.90±0.68	0.800 - 6.16
HGH - CC	6.12±2.60	1.60 – 23.12	1.78±0.66	0.589 – 6.13
NCCCR -MLO	6.50±1.96	3.22 – 16.60	1.80±0.68	0.827 - 5.82
HGH - MLO	6.91±2.72	1.63 – 23.45	1.97±0.69	0.710 – 6.13

The statistics shows that, the ESAK mean values ranged between 6.12 to 6.91 mGy through the ESAK dose range between 1.6 to 23.45 mGy for all projections. The MDG mean values ranged between 1.78 to 1.97 mGy through dose range between 0.598-6.16 mGy.

In General the MGD values for MLO views are larger than those for CC views. Significant differences were found between MGD from CC and MLO views (p<0.006).

To be able to compare our data with the European guidelines, the thicknesses for both hospitals have been selected accordingly as shown in Table 6.

Table 6. Illustrates the 428 exposures that have exact thickness compared with the European guidelines

CBT *cm*	HGH		NCCCR	
	No	Within limit	No	Within limit
2.0	0	0	0	0
3.0	09	08	02	01
4.0	30	29	07	0
4.5	46	45	16	09
5.0	71	71	34	32
6.0	86	86	35	35
7.0	58	58	34	34

It was found that, there were 428 exposures that had the same European guidelines thickness and 95.32% were within the limit (408 out of 428 exposures).

The statistics showed that, the MGD range for all patients (two machines) is 0.71–6.16 mGy through the thickness 2.5-7.0 *cm*.

Referring to the current guidance for the mammography which adopts 3mGy as a dose level for standard breast (4.5 *cm*), it is still within the recommended limit by IAEA as summarized in Table 7.

Table 7. Illustrates the statistics of the 62 exposures done on the ideal breast thickness (4.5 *cm*) and comparing with the IAEA limit (3 mGy)

Hospitals	Exposure No	Less than 3 mGy	More than 3 mGy
NCCCR	16	14	2
HGH	46	45	1
Total	62	59	3
Percentage %		**95.2**	**4.8**

From the selected patients only 62 exposures compiled with the IAEA for the ideal breast thickness (4.5 cm), 16 and 46 exposures from both hospitals NCCCR and HGH respectively. Due to compression devise error such as the ratio between measurement error and mean value while there are defect in the breast thickness indicator (gives higher than the real thickness) so, the machine select wrong parameters which increase the MGD. In the NCCCR mammography machine, the MGD of some patients become more than the acceptable values especially at small compressed breast thickness values which presented in Table 8 and Fig. 2.

Ratio between measurement error and mean value.

From Table 8 and Fig. 2, all exposures done in NCCCR which fall in the fatty group (5-7 *cm*) are in acceptable range. 23.7% from the medium group are out of the acceptable limit (47 out of 198). 0% in the acceptable range in the thickness range 2 – 3 *cm*.

Regarding the HGH, 99.7% from the exposures are in the acceptable limit presented in Table 9 and Fig. 3.

The statistics from Table 9 showed that, 12% out of the limit (3 out of 25) in the dense group (2-3 c*m*). 0.7% out of the limit (5 out of 751) from the medium group (3-5 *cm*) and all exposures fallen in the fatty group are acceptable.

After exposing the delivered mAs and kVp were automatically measured for each exposure by the Barracuda system and also read from the council of machine. The exposure parameters were recorded for each patient and the average of them obtained for each group according to the thickness. Then the average of exposure parameters were used as a clinically exposure parameters for phantom exposing and MGD determining. Table 10 presented the summary of the radiological parameters used for this study.

Table 11 showed the comparison between the measured MGD values in this study for digital mammography and some published values from other studies for film screen mammography.

Although the values in the present study were found to be in between of the published values, which used conversion factors from the same source, authors who used the same source in

Table 11 did not follow the same method for the determination of air kerma. Thus, any difference in methods used to obtain air kerma may partially contribute to any difference in MGD values. In addition, those studies for screening which are present in this study are not for diagnostic purposes. Also, other factors such as difference in patients' anatomies and in X-ray units may have contributed to the differences in the MGD values.

Table 8. Distribution of calculated MGD and MGD range by Patients' groups in NCCCR

Group	Exposure No	Mean ± SD	Range mGy	Out limit
2 – 3	5	3.51±0.7	2.5 - 4.4	5
3 - 5	198	2.5±0.8	1.2 - 6.16	47
5 - 7	746	1.7±0.5	0.8 - 4.60	0
Acceptable MGD Doses %			94.50%	

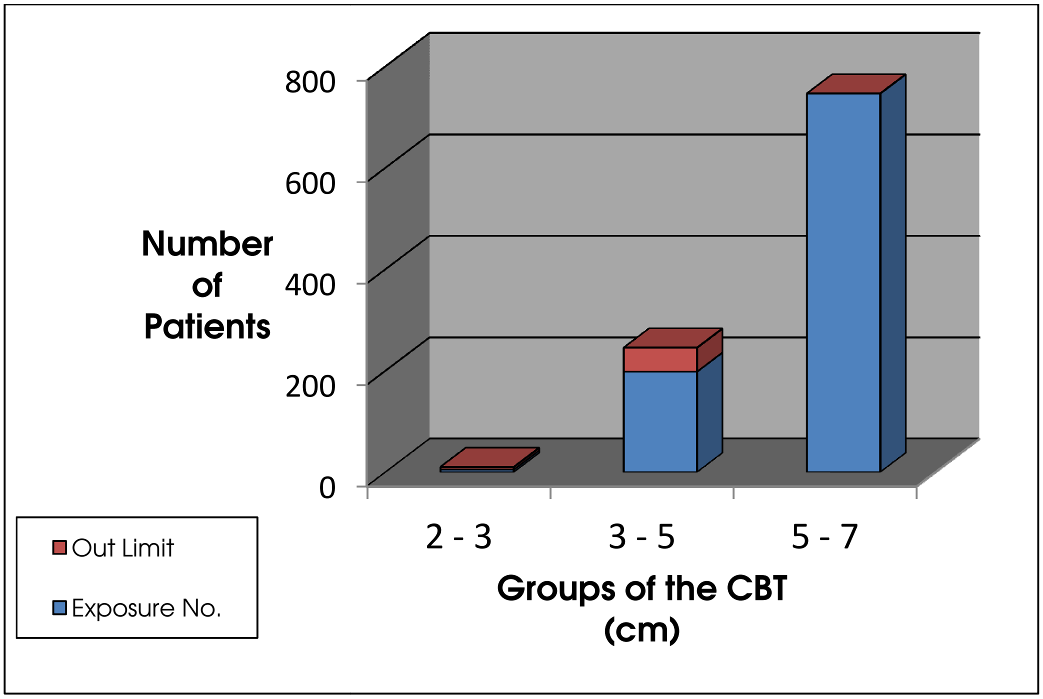

Fig. 2. Distribution of calculated MGD by Patients' group in NCCCR

Table 9. Distribution of calculated MGD and MGD range by patients groups in Hamad General Hospital HGH

Group	Exposure No	Mean ± SD	Range mGy	Out limit
2 – 3	0025	1.60±0.40	0.71 - 2.54	3
3 - 5	0751	1.36±0.40	0.58 - 3.57	5
5 - 7	1555	2.02±0.65	0.60 - 6.10	0
Acceptable MGD Doses %			99.70%	

Table 10. Mean +/-SD and range of exposure factors used in this study

Projection	kV		mAs	
	Mean ±SD	Range	Mean ±SD	Range
NCCCR - CC	29±1.6	25 - 32	79.63±22.70	27.3 – 177.9
HGH - CC	29.6±1.5	26 - 32	139.40±49.40	47 – 456.0
NCCCR - MLO	29.69±1.7	24 - 32	86.60±24.60	33.5 – 178.6
HGH - MLO	30±1.4	26 - 32	153.45±52.14	54 – 467.0

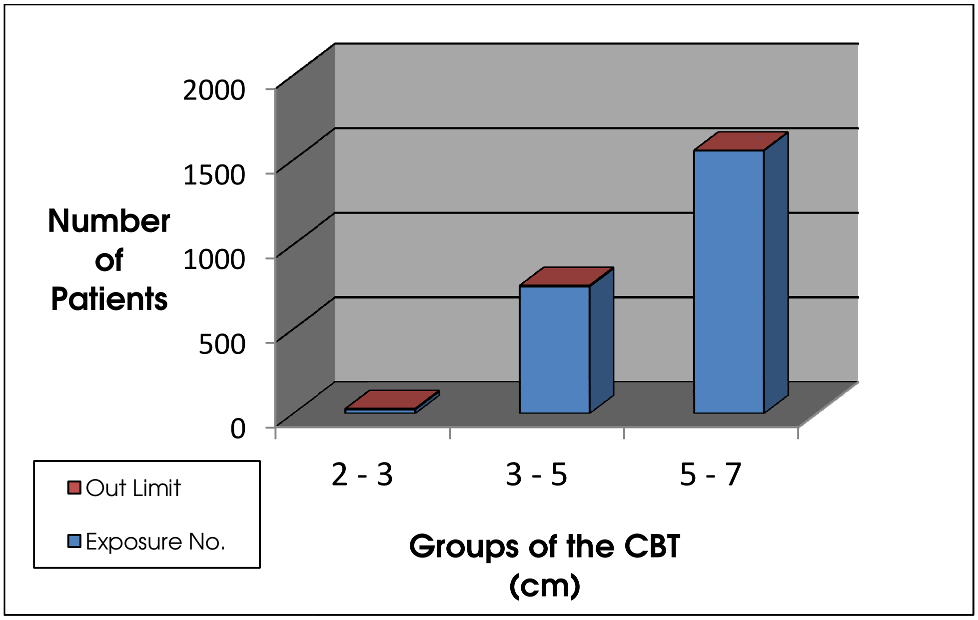

Fig. 3. Distribution of calculated MGD by patients' group in HGH

Table 11. Comparison of estimated MGD values of present study to some published values

Author	**Country**	**MGD (mGy)**	
		CC	**MLO**
Burch and Goodman [12]	UK	1.63	1.93
Young and Burch [13]	UK	1.65	2.03
Jamal et al. [14]	Malaysia	1.54	1.82
Young et al. [15]	UK	1.96	2.23
Ogundare et al. [16]	Nigeria	0.33	1.43
Bouzarjomehri et al. [17]	Iran	1.20	1.63
Irene et al. [18]	Ghana	1.17	1.25
Leili rahmatnezhad. [19]	Iran	1.18	1.39
This study	**Qatar**	1.84	1.885

Generally, measuring the MGD directly is not achievable, due to the need of measuring the entrance surface exposure with taking into consideration the different factors which affect the MGD value such as kVp, target/filter combination, breast thickness and the beam quality (HVL). Hence, there are many factors that can affect the mean glandular dose. In our study, two main factors including HVL and CBT had the most affect on the MGD per exposure. Jamal et al. [14] has evaluated MGD for 300 women from three ethnics, and found that the difference of MGD per woman is the result of X-ray tube output, exposure factors, CBT and breast type. The factors affecting MGD per woman were tested for significance using a multivariate analysis of variance. The MGD for the phantom was 1.23 mGy (range 0.22–2.39 mGy) while the mean patient based MGD per film was 1.54 mGy and 1.82 mGy for the craniocaudal and mediolateral oblique views, respectively. The mean MGD per woman was 3.37 mGy [14].

4. CONCLUSIONS

The present study revealed that there were significant differences between the MGD values for the CC and MLO views ($p < 0.006$). The average MGD of 1.885 mGy and 1.84 mGy for the MLO and CC views respectively in this study was found to be lower than the recommended guidance value of 3.0 mGy and compared to some other published values.

The two mammography machines out of three machines covering more than 93% of all mammography exposures in Qatar can be considered as preliminary estimation for the mammography DRL in Qatar.

According to the method provided in Appendix 1 of EUREF European guidelines, the result indicated that 99.7% and 94.5% are within the limits for HGH and NCCCR respectively. Due to compression devise error in the NCCCR mammography machine, the MGD for some patients became more than the acceptable values especially at small breast thickness values (0-3 *cm*) which it seems 0% in the acceptable range.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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