

An Investigation of Mean Glandular Dose from Routine Mammography in Urmia, Northwestern Iran and the Factors Affecting It

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Abstract: The objective of this study was to determine the Mean Glandular Dose (MGD) resulting from Craniocaudal (CC) and Mediolateral oblique (MLO) views in one breast and the total dose per woman in Urmia, northwestern Iran and to identify the factors affecting it. This study was conducted during 9 months to estimate the MGD for women undergoing mammography and to report the distribution of dose. The clinical data were collected from 460 mammograms taken from 230 women who were referred to radiology center of Imam Reza hospital in Urmia. The piranha system version 3.8A was used for determining the MGD in this work. The MGD values are based on measurements of ESAK (entrance surface air krama) and HVL. Significant differences were found between MGD from CC and MLO views. The mean±SD MGD per film was 1.18±0.38 mGy for craniocaudal and 1.39±0.51 mGy for mediolateral oblique views, (p<0.001). The mean±SD MGD per woman was 2.57±0.44 mGy. The mean±SD MGD per film in present study were lower than most of similar reports. The dose values obtained fall within the internationally acceptable dose range of 1-3mGy. This suggests mammography x-ray generators in this part of the country are capable of achieving acceptable dose levels for patient safety. Therefore, with considering the all other factors, the establishment of screening mammography program is achievable.

Key words: Compressed Breast Thickness (CBT), Entrance Surface Air Crema (ESAK), Mammography, Mean Glandular Dose (MGD)

INTRODUCTION

Breast cancer is reported as one of the first causes of women mortality (Smith, 1991). Mammography is, nowadays, the most effective and accurate method for early detection of breast cancer (Tomal *et al.*, 2010). Cancer detection relies on the difference in the X-ray attenuation coefficient between normal and pathological tissue (Golosio *et al.*, 2009). Radiation dose absorbed by the breast tissue has been suggested as a risk factor in the mammographic procedure, since it can trigger carcinogenesis (Brenner *et al.*, 2002). Furthermore, dose distribution inside breast is a very important issue, since radiation sensitivity varies among the different tissues of breast. (Delis *et al.*, 2005). The average absorbed dose by glandular tissue is the most appropriate information for risk assessments associated with mammography (Dance, 1990; Dance *et al.*, 2000). Breast dose is also a key parameter in the establishment of local, regional and national standards (Dance *et al.*, 1999).

In mammography, the dose parameters that are usually used are the Entrance Surface Dose (ESD), skin dose, midplane glandular dose, average whole-breast dose

and Mean Glandular Dose (MGD) (Ogundare *et al.*, 2009). The MGD is an index of mammographic dosimetry derived from the ESD (Tsai *et al.*, 2010). MGD provides the best indicator of the risk to the patient from a mammographic examination (Dance, 1990; NCRP, 2004). This is because it is commonly assumed that cancer risk is linearly related to MGD and that breast cancers arise in the glandular tissue (Matsumoto *et al.*, 2003).

In most practical situation the MGD is derived from the product of the measured entrance air kerma and appropriate conversion factors of normalized average glandular dose (Wu *et al.*, 1994; Dance, 1990; Wu *et al.*, 1991). Air kerma measurements can be made using either thermoluminescent dosimeters (TLDs) or ionization chamber (Ogundare *et al.*, 2009). It can also be estimated using the X-ray machine exposure parameters used for the patient. However, for direct measurements on patient breast the most suitable approach is the use of TLDs (Gentry and DeWerd, 1996; Nassivera and Nardin, 1997).

The standard mammographic protocol for screening always includes two views, craniocaudal and mediolateral oblique (Eklund and Cardenosa, 1992). The angle of 45°

is usually suitable for the majority of patients in routine daily practice (Brnic and Hebrang, 2001). Patient dose measurements in mammography are important for reasons that include evaluation of risk to a patient in a screening program and for assessment and comparison of techniques and equipment (Ogundare *et al.*, 2009; Rothernberg, 1990).

The purpose of this study was to estimate glandular absorbed radiation doses in the two standard views, craniocaudal and mediolateral oblique at the Imam Reza hospital in the Urmia City of Iran and to evaluate the mean glandular dose as a function of the thickness and composition of the breast. In addition, to compare the glandular absorbed radiation doses with the international standard doses.

MATERIALS AND METHODS

Patients: Data was collected from women undergoing routine mammography over the period from March 2011 to November 2011. During 9-month period the two standard mammographic views (craniocaudal and mediolateral oblique 45°) were investigated on 230 patients. The patient's demographic information is shown in Table 1. With respect to the breast size, the women were categorized in three groups (small, medium and large).

Equipments: The X-ray unit used for this study was a Planmed Sophie Classic with high-frequency X-ray generator. The rotating anode had a grounded molybdenum target with nominal, selectable focal spot sizes of 0.1 and 0.3 mm. The X-ray unit has an inherent filtration of 1.0 mm beryllium and dual motorized filters, one is 30 μm Mo with 0.5 mm Al and another is 30 μm Mo with 25 μm Rh, which automatically changed.

The breast substitute material used for the study was Euro-Mammography-Phantom, (Pehamed). The film and screen type used were AGFA Mamoray High-Dynamic Range (HDR) and AGFA Mamoray (high-dynamic screen), respectively. For film processing, an AGFA Imaging Min/Med unit maintained at a temperature of 34.9°C with a processing cycle of 90 s was used.

The Piranha system version 3.8A was used for determining the MGD in this study. This system has an external dose probe which designed for determining the input dose to medium or phantom. The detector's main part is a PIN semiconductor photo diode. The diode detects the X-rays and produces a current proportional to the intensity of the X-rays. The currents, and charge, produced by the photo diode can be measured with an electrometer and converted to values of the air kerma or dose.

Calibration of tube output: For this study, the tube output was measured for tube voltages set at 25-32 kV

Table 1: Patients distribution by age and projection

Age group (years)	Number of CC view	Number of MLO view
30-40	23	23
41-50	96	96
51-60	82	82
61-70	17	17
71-80	12	12

Table 2: The Tube Output values of the mammography X-ray machine measured and the HVL values at the specified nominal tube voltages

Nominal tube voltage (kVp)	Out put (μGy/mAs)	HVL (mm Al)
25	0.11±0.02	0.28
26	0.12±0.02	0.29
27	0.15±0.01	0.30
28	0.16±0.02	0.31
29	0.19±0.01	0.32
30	0.20±0.02	0.33
31	0.28±0.01	0.34
32	0.28±0.01	0.35

Table 3: Number of Projections and mean ± SD of exposure factors of patients included in this study.

Patients groups	Number of Projections Kvp mAs			
	CC	MLO	Range	Mean±SD
Small (≤ 3.5cm)	42	42	25-27	37.16±7.30
medium (>3.5; ≤5.5cm)	112	112	26-30	40.12±9.40
large (>5.5cm)	76	78	28-32	43.32±11.60

with 1 kV step. The measurements were all carried out with the breast compression plate in place. The tube output measurement has been expressed as air kerma /TL (tube loading) (μGy/mAs) at 1m focus-detector distance (Assiamah *et al.*, 2005). The Half-Value Layers (HVLs) at the specified nominal kVp obtained by the following formula (Minister of health Canada, 2002):

$$HVL(mm\ of\ Al\ min\ um) \geq \frac{x - Ray\ Tube\ Voltage(KV)}{100} + 0.03 \quad (1)$$

The Tube Output values of the mammography X-ray machine measured in the presence of the breast compression plate used for this study and the HVL values at the specified nominal tube voltages are shown in Table 2.

Methods: In this study patients based on the breast size were categorized in three groups (Table 3). The patients were exposed in an upright position. In this regarding, the X-ray machine was set up for two standard views separately, with the breast compression plate and a loaded cassette in place. Tube voltage is set by the radiographer and appropriate mAs were engaged automatically, by the AEC- (Automatic Exposure Control) system.

After exposing the delivered mAs and kVp were automatically measured for each exposure by the piranha 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. Then the



Fig. 1: The mammography x-ray generator and dosimetry unit

average of exposure parameters were used as a clinically exposure parameters for phantom exposing and MGD determining. Table 4 shows the summary of the radiological parameters used for this study.

In dosimetry process, the X-ray machine was set up for two standard views separately, with the breast compression plate and a loaded cassette in place. The phantom was placed on the breast support table and the external dose probe of piranha system was placed on the phantom. The compression plate was brought down onto the phantom (Fig. 1). The mean exposure parameters recorded from each group was used for phantom and external dose probe exposing. The measured data were recorded for each exposing. Each exposure repeated three times for reducing the measurement errors. Thus dose values represent the averaged values obtained from three separate measurements made for every group.

Determination of MGD: The most common measurements for a mammographic system are conducted to determine the Mean Glandular Dose (MGD). The MGD values are based on measurements of ESAK (entrance surface air kerma) and HVL. To do the measurements correctly and according to standards, the radiation detector placed directly below the compression paddle. This introduces extra scattered radiation due to the compression paddle which is important to include when determining ESAK. On the other hand, the HVL measurement should be done without any scatter contribution and with good geometry.

“The MGD was calculated from the ESAK (without backscatter), obtained from the output measurements and standard conversion factor tabulations and the equation:

$$MGD = K_{gp} \tag{2}$$

where K is the ESAK at the specified HVL, and g is the ESAK-to-MGD conversion factor. The P-factor converts air kerma for the PMMA breast substitute phantom to that for the model breast, which it approximately simulates (Dance *et al.* 1999). All the MGD values presented are for a Focal-Spot-to-Detector distance (FSD) of 650 mm. The conversion factors g and p, used for this study, were those

Table 4: Mean±SD and range of exposure factors used in this study

Projection	KV		mAs	
	Mean±SD	Range	Mean±SD	Range
CC	27.20±1.60	25-30	35.80 ±9.60	21-64
MLO	29.30±2.40	26-32	44.60±11.40	26-86
ALL*	28.25 ±2.90	25-32	40.20±12.20	21-86

* Data for both CC and MLO views

Table 5: Mean ± SD and range of measured ESAK and calculated MGD.

Projection	ESAK (mGy)		MGD (mGy)	
	Mean ±SD	Range	Mean ±SD	Range
CC	6.24±1.32	3.15-8.82	1.18 ±0.38	0.32-1.66
MLO	7.36±2.27	3.88-10.36	1.39 ±0.51	0.41-2.18
ALL*	6.80±2.06	3.15-10.36	1.28 ±0.47	0.32-2.18

* Data for both CC and MLO views

Table 6: Distribution of Mean± SD calculated MGD and CBT by Patients' groups

Patients' groups	CC view		MLO view	
	MGD (mGy)	CBT (mm)	MGD (mGy)	CBT (mm)
small	0.94±0.033	≤ 3.5cm	1.10±0.042	≤ 3.5cm
medium	1.28±0.010	>3.5 ; ≤5.5cm	1.51±0.024	>3.5 ; ≤5.5cm
large	1.33±0.003	>5.5cm	1.56±0.004	>5.5cm

from Dance (1990) and were calculated assuming the standard breast phantom composition. The g factors for the measured half-value layers were derived by interpolation from the compiled data and gave a percent deviation of less than 5% (Assiamah *et al.*, 2005).” Compressed Breast Thickness (CBT) was measured to the nearest 0.5 mm using a ruler as the distance between the bottom of the compression plate and the table upon which the breast rested. For CC views, measurement of CBT was made on left and right sides of the compression plate, and the mean value was calculated (Jamal *et al.*, 2003). “In the case of MLO, measurement was made at only one side of the compression plate, opposite to the woman arm. Mean Glandular Dose (MGD) was calculated as:

$$MGD = (ESD/BSF) \times D_{gn} \tag{3}$$

where, D_{gn} is the air kerma to MGD conversion factor and BSF is the appropriate mammographic backscatter factor. The factor D_{gn} is usually expressed in units of mGy/mGy (Ogundare *et al.*, 2009).” It must be noted that in this study the MGD per woman was the MGDs sum of two views of each breast.

RESULTS

In this study, 230 women 30-80 years old were included. Mean age was 51.3±8.7 years. The summary of the radiological parameters used for this study are listed in Table 4.

Results of the measured ESAK and calculated MGD are summarized in Table 5. In this study the mean (±SD) CBT value for CC view is 41.8±0.63 mm which is lower than 50.3±0.46 mm for MLO views. The ESAK values for MLO views are larger than to those for CC views. MGD values followed the same trend. Significant

Table 7: Comparison of estimated MGD values of present study to some published values.

Author	Country	MGD (mGy)		
		CC	MLO	Source of D _{gn}
Burch and Goodman (1998)	UK	1.63	1.93	Dance (1990)
Young and Burch (2000)	UK	1.65	2.03	Dance (1990)
Jamal <i>et al.</i> (2003)	Malaysia	1.54	1.82	Dance (1990)
Young <i>et al.</i> (2005)	UK	1.96	2.23	Dance (1990)
Bouzarjomehri <i>et al.</i> (2006)	Iran	1.2	1.63	Sobol and Wu (1997)
Ogundare <i>et al.</i> (2009)	Nigeria	0.33	1.43	Wu <i>et al.</i> (1991)
Irene <i>et al.</i> (2011)	Ghana	1.17	1.25	Wu <i>et al.</i> (1991)
Present	Iran	1.18	1.39	Dance (1990)

differences were found between MGD from CC and MLO views ($p < 0.001$).

The variations of average MGD and Compressed Breast Thickness (CBT) with Patients groups are presented in Table 6. The table showed that both MGD and CBT increase with increasing breast thickness.

DISCUSSION

The radiation dose expresses as the energy deposited or absorbed in a specific tissue. The glandular tissue of the breast is the radiosensitive tissue (Sechopoulos *et al.*, 2008). The mean glandular dose is the most common quantity used to represent the risk from the ionizing radiation used in the mammography screening, because of the sensitivity of the mammary glands (Mohammad, 2009). The mean age of the study women was 51.3 years (range 30-80 years) which coincides with the age of menopause. During the menopause period significant changes in composition of breast occur (Beckett and Kotre, 2000). In the present study the mean age was also similar to the values recorded by other authors (Ogundare *et al.*, 2009; Jamal *et al.*, 2003; Irene *et al.*, 2011).

The analysis of the exposure factors showed that both kV and mAs were higher for MLO views than for CC views (Table 4). This could be explained by the presence of pectoral muscle in the oblique view as stated previously by Young and Burch (2000). It seems that the high exposure factor of MLO views is the main reasons of the need to prevent unnecessarily patient dose.

The mean±SD CBT for CC and MLO views were 41.8±0.63 and 50.3±0.46 mm, respectively. CBT values for CC and MLO views in the present study were somewhat large than the values recorded by Jamal *et al.* (2003) and Ogundare *et al.* (2009). The CBT values for CC and MLO views were also somewhat less than the values recorded by Irene *et al.* (2011). The difference in mean CBT of MLO and CC views is 25.2%. This difference is larger than that found in UK (5.4%), US (9.1%) and Malaysia (18.7%) (Irene *et al.*, 2011; Helvie *et al.*, 1994; Jamal *et al.*, 2003) and also less than that found in Nigeria (30%) (Ogundare *et al.*, 2009). This may represent a difference in the compression force used, a difference in the thickness measurement technique and a main difference between the populations as previously mentioned by Jamal *et al.* (2003).

The MGD in Table 5 shows that the mean MGD per film for the MLO (1.39±0.51) was % 15 higher than that for CC view (1.18±0.38). The higher doses of MLO views are due to the use of higher mAs and CBT values for this view. The mean±SD MGD per woman (from one breast) was 2.57±0.44 mG. In this study the dose values obtained fall within the internationally acceptable dose range of 1-3mGy when using grid (IAEA, 1996).

From Table 6 we also found that the average MGD increases with CBT. This result is consistent with the findings of other authors that have reported the relation between the two parameters. They found that average MGD increases exponentially with CBT (Young *et al.*, 2005; Ogundare *et al.*, 2009).

Table 7 shows the comparison of MGD values between in this study and some published values from other studies. The values in the present study were found to be somewhat below the published values, which used conversion factors from the same source as in this study. Because the authors that used the same source in Table 7 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, other factors such as difference in patients' anatomies and in X-ray units may have contributed to the differences in the MGD values.

Generally, measuring the MGD directly is not achievable, due to the need to measure the entrance surface exposure, taking into consideration the different factors which affect the MGD value-for example the kVp, target/filter combination, breast thickness and the beam quality (HVL) (Dance, 1990). Hence, there are many factors that can affect the mean glandular dose. In our study, two main factors including HVL and CBT have the most affecting on the MGD per woman. Jamal *et al.* (2003) 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. This report has given the MGD/film for CC view as 1.44 mGy, comparable with 1.18±0.38 mGy in our study.

They reported value of 1.44 mGy as an average MGD per film for CC views, comparable with 1.18±0.38 mGy in our study. Considering the effects of two main factors on the MGD it must emphasize that the HVL is an indirect measure of the x-ray energy and influences the

amount of energy deposited. It is well known that, increasing the kVp increases the quality of an x-ray beam (HVL). So, increasing photon energy (HVL) generally decreases the probability of interactions and, therefore, increases penetration. This emphasizes the principle that minimizing HVL will maximize MGD. While CBT influences the length of x-ray passage through the breast and consequently, the energy absorption. So, the strong compression of breast and can reduce the dose needed to imaging by reducing the thickness of the breast and consequently reducing MGD.

CONCLUSION

The present study revealed that there are significant differences between the mean MGD values for the CC and MLO views ($p < 0.001$). The average MGD of 1.39 mGy and 1.18 mGy for the MLO and CC views respectively in present study were found to be lower than the recommended guidance value of 3.0 mGy and some other published values. Considering the average MGD of 2.57 mGy per woman in this study it is concluded that the quality control program had been established in this center and the mammography doses are acceptable. It is recommended that to establish the practice of screening mammography program in this part of the country, further studies should be done on the other factors that are required for an appropriate screening program.

ACKNOWLEDGMENT

The authors would like to thank the staff of the Medical Imaging Center of Imam Reza Hospital of Urmia. In this regard, special thanks goes to Mr Seid Abdolreza Sotodegan for providing access to the Mammography machine and help in performing initial experimental measurements.

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