ORIGINAL ARTICLE

Mean Glandular Dose Measurement in Three Mammography Centers in Kashan: An approach to Provide a Local DRL

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Abstract

Purpose: Mammography is the most important diagnostic modality for early detection of breast cancer, however, concerns related to the side effects induced by ionizing radiation are still present. In the current study, the Mean Glandular Dose (MGD) values for mammography examinations as well as a local Diagnostic Reference Level (DRL) were obtained for mammography centers in Kashan, Iran.

Materials and Methods: Three mammography devices from three radiology centers were selected to obtain the MGD values of mammography examinations. To assess the MGD values, the technical parameters for patients' imaging at these three radiology centers were extracted. Then, the incident air kerma (in mGy) value received by each patient was measured by a UNIDOS E electrometer (PTW, Germany) along with a SFD mammography ionization chamber (PTW, Germany). Finally, the incident air kerma values were converted to the MGD values by specific conversion factors. Based on the obtained MGD values, a local DRL was also established for mammography examinations.

Results: Mean MGD values per exposure were obtained 2.39 ± 1.46 mGy for Right Craniocaudal (RCC), 2.64 ± 1.67 mGy for Left Craniocaudal (LCC), 2.82 ± 1.89 mGy for Right Mediolateral Oblique (RMLO), and 3.09 ± 1.90 mGy for left mediolateral oblique views. Moreover, a local DRL obtained from mammography examinations, which was established as the overall median of MGD value, was 1.72 mGy (1.91 mGy for digital and 1.32 mGy for analog mammography).

Conclusion: The MGD values for different views obtained in this study are in the range of previously reported values. Considering the European guidelines for quality assurance in breast cancer screening and diagnosis, it can be mentioned that the obtained DRL was less than the recommended dose level (2.0 mGy).

Keywords: Mammography; Mean Glandular Dose; Diagnostic Reference Level; Iran.

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1. Introduction

Breast cancer is the most common cancer among Iranian women and other women all around the globe [1, 2]. In Iran, this cancer includes 24.4% of all female cancers with the age-standardized rate of 23.1 per 100000 [3, 4] and is the fifth most common cause of death from cancers among Iranian women [3]. Iran, a developing country, faces an increment in breast cancer incidence [3-5]. Due to this, early detection of breast cancer can be a significant factor in reducing the burden [3, 4]. Based on the information, breast cancer screening is not performed for a large fraction of women in Iran; hence, this may lead to a delay in detection of this cancer and increase the death rate of Iranian women with breast cancer [6, 7].

In diagnosing breast cancer, various imaging modalities are being utilized such as mammography, sonography, magnetic resonance imaging, magnetic elastography as well as magnetic spectroscopy [8]. Mammography is considered the most important diagnostic modality for the early detection of breast cancer [9]. In addition, it can be used for women with no signs or symptoms of breast cancer [10]. Moreover, microcalcifications can be detected in this imaging modality that they sometimes demonstrate the presence of breast cancer [11].

Any mammography examination aims to acquire accurate diagnostic information with an acceptable delivered radiation dose to the breast tissue; therefore, mammography examination needs to be justified in terms of radiation protection [12]. However, concerns related to the side effects induced by ionizing radiation applied in mammography are still present. It has been reported that mammography examination may lead to an increase in the incidence of breast cancer [8]. Therefore, it is necessary for regular dose monitoring during mammography screening. Additionally, the knowledge of the dose absorbed into breast tissue is essential for the design and performance evaluation of mammographic imaging systems.

In mammography, the potential risk of radiation-induced breast cancer can be estimated following the Mean Glandular Dose (MGD) quantity; because the glandular tissue is the most sensitive of breast tissue to ionizing radiation [13-15]. MDG is defined as the absorbed dose averaged over the whole fibroglandular tissue in the breast [16]. This quantity cannot be measured directly, as it can be obtained from Compressed Breast Thickness (CBT) and incident air kerma using proper conversion factors [17, 18]. The two main methods for evaluating MGD arising from mammography are; a patient-based measurement and a standard breast phantom-based measurement [19].

While several studies have been previously conducted in Iran and other countries to assess the MGD values from mammography examinations [12, 19-23], to the best of our knowledge, there is no similar study performed in Kashan. Moreover, each radiology center needs to assess its MGD values that can be used in estimating cancer risk from mammography examinations and also the performance evaluation of mammographic imaging system. Thus, the present study aimed to determine the MGD values from mammography examinations in three radiology centers in Kashan. Additionally, the findings of the present study were compared with international standard levels and published data from other researchers. Furthermore, this study intended to establish mammographic local Diagnostic Reference Level (DRL) for MGD in Kashan, Iran.

2. Materials and Methods

Three mammography devices from three radiology centers in Kashan (namely; A, B, and C) were selected, in such a way that the MGD values can be calculated. Two mammography devices installed at radiology centers A and C were equipped with digital-based imaging systems and another radiology center (B) was equipped with a screen-film mammography system. The characteristics of these units are listed in Table 1.

In total, the exposure parameters of 264 mammograms requested by the physicians at the three radiology centers were used for MGD estimation. It is noteworthy that mammograms obtained in Right Craniocaudal (RCC), Left Craniocaudal (LCC), Right Mediolateral Oblique (RMLO), and Left Mediolateral Oblique (LMLO) views were included in this study.

For each patient, the exposure parameters, including kVp, mAs, target, and filter type, mammogram views, and CBT at these three radiology centers were extracted. It must be noted that the quality control procedures as recommended by the Iranian atomic energy agency (including kVp, mA, and exposure time accuracy, repeatability, stability) were performed for all the devices used in this study to assure that all of the exposure parameters are within the range of acceptable precisions.

Table 1. Characteristics of the mammography devices applied in the current study

Technical Parameters of Mammography Units	Radiology Center		
	A	B	C
Manufacturer	PAYAMED	IAE	PAYAMED
Nation/Country	Iran	Italy	Iran
Mammography machine	PMA 100FD	XM12	PMA 100F
Anode material	Molybdenum	Molybdenum	Molybdenum
Filtration	Silver (50 μm)	Beryllium (0.5 mm)	Molybdenum (30 μm)
Maximum peak voltage	35 kV	40 kV	35 kV
Half-Value Layer (HVL)	0.65	0.7	0.47

To calculate the MGD value for each view, the exposure parameters of each patient were first simulated, and then the incident air kerma (in mGy) was measured using a UNIDOS E electrometer (PTW, Germany) along with a calibrated SFD mammography ionization chamber (6 cm^3, Model 79115, PTW, Freiburg, Germany). The air kerma was measured without the presence of patients for each set of exposure parameters. Notably, the average value (obtained from three times of the measurement for each patient) was considered as the incident air kerma value for that set of exposure parameters. Finally, the incident air kerma values were converted to the MGD values by the conversion factors described by Dance *et al.* [24] (Equation 1):

$$MGD = K_i \times g \times c \times s \qquad (1)$$

Where K_i is the incident air kerma (in mGy), g is a conversion factor of Ki to MGD for breast with 50% glandularity, c is a correction factor for any difference in glandularity other than 50%, and s is a correction factor for any difference in the X-ray spectrum produced by a tube with molybdenum anode and filter. Notably, g and c factors are dependent on tube voltage and CBT, while s factor is dependent on X-ray spectrum [17, 24, 25].

In the present work, the median of mean MGDs was calculated to obtain the DRL values.

3. Results and Discussion

The mean recorded exposure parameters used in the three mammography devices for the RCC, LCC, RMLO, and LMLO views are presented in Figure 1 (kVp values) and Figure 2 (mAs values). The mean CBT values for the above-mentioned views in the three centers are shown in Figure 3.
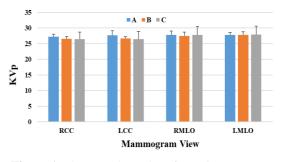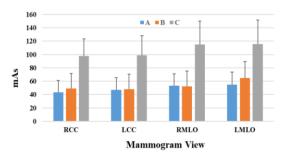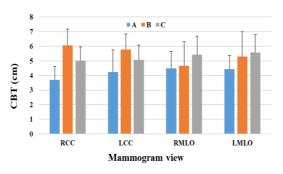

Figure 1. The mean kV values for various mammogram views at the three radiology centers

Figure 2. The mean mAs values for various mammogram views at the three radiology centers

Figure 3. The mean CBT values for various mammogram views at the three radiology centers

The mean MGD per exposure was 2.39 ± 1.46 mGy for the RCC view, 2.64 ± 1.67 mGy for the LCC view, 2.82 ± 1.89 mGy for the RMLO view, and 3.09 ± 1.90 mGy for the LMLO view.

Findings revealed that the mean MGD values per exposure for the MLO views were higher than those of the CC views. To justify this, the presence of the pectoral muscle in the MLO views leads to a higher attenuation of radiation exposure, such that the radiation exposure absorption increases. The mean MGD values for various mammogram views at the three radiology centers are shown in Figure 4. Notably, the variations of the MGD values at different radiology centers could be attributed mainly to the use of different mAs values (Figure 2); as the mean MGD value in radiology center C was higher than the other two centers, because of higher mAs in this center. The other parameter which can affect the MGD values is the type of filtration. As it is clear from Figures 1 and 2, the kVp and mAs of the systems in the center A (digital) and B (analog) are relatively similar. However, according to Table 1, the filter materials are different in the centers' A and B, which are Silver (Ag) and Beryllium (Be), respectively. The different atomic number of filters (47 for Ag vs. 4 for Be) cause different radiation spectrums. Since in the studied device of B, the Be thickness was higher and the atomic number was lower, as a result, a higher attenuation of lower energies will occur that can cause a lower dose delivered to the breast.
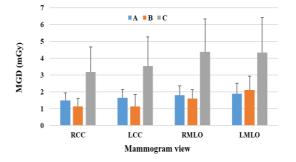

Figure 4. The mean glandular dose (MGD) values for various mammogram views at three radiology centers

Higher MGD values can lead to increase cancer risks. In other words, the linear no-threshold model, which was used as an acceptable method to estimate the risk of low-level ionizing radiation, represents that; there is no safe level of ionizing radiation exposure; therefore, any radiation dose can lead to genetic mutations or cancer [26-28]. In general, it can be concluded that patient dose is mainly related to exposure parameters like kVp, mA, Sec, filtration, and field of view. It is expected that higher exposure parameters lead to higher patient doses. Digital detectors used in digital radiography systems have higher dynamic ranges (potentially having higher contrast) as they can produce images with acceptable diagnostic quality at lower exposures. However, they can also produce acceptable images with higher exposure parameters (or even in overexposed conditions) [29].

In this study, the exposure parameters of the patients undergoing mammography in the three radiology centers were only recorded without any intervention. It was observed that the MGD values were higher in a center with a digital mammography system (center C) compared to a center having an analog system (center B), and this could be attributed to the higher exposure parameters in a digital system. In this regard, a dose reduction program is highly recommended for implementation. Moreover, the periodic assessments of MGD values can help in improving the overall performance of mammography devices in terms of radiation dose as well as image quality.

Some studies have reported the MGD values from mammography examinations. In a study by Jamal *et al.* [19], the mean MGD values from mammography examinations in Malaysia were obtained. In that study, 300 women from three major ethnic groups of Malay, Chinese, and Indian were included. They reported that the MGD per woman for Malay, Chinese, and Indian were 3.36, 3.31, and 3.44 mGy, respectively. However, there was no significant difference in MGD value per woman among the ethnic groups. Moreover, the mean MGD per film was 1.82 mGy and 1.54 mGy for CC and MLO views, respectively [19]. Ciraj-Bjelac *et al.* [12] assessed mammography dose levels in Serbia. The phantom dose measurements at 30 mammography units revealed a mean MGD value of 1.9 ± 1.0 mGy (0.12–5.2 mGy) [12]. Tsapaki *et al.* [20] investigated breast dose arisen from screening mammography in five radiology centers in Greece. They reported that the average MGD value per exposure was 1.4 ± 0.6 mGy. In details, the average MGD value per exposure for the MLO and the CC views were 1.5 ± 0.7 and 1.2 ± 0.5 mGy, respectively [20]. Moran *et al.* [30] analyzed the MGD values obtained from screening mammography of 5,034 patients in Spain. They reported the mean MGD values of 1.95 and 1.8 mGy for the MLO and CC views, respectively [30]. Alizadeh Riabi *et al.* [22] evaluated MGD values arisen from a mammography unit in Tabriz, Iran. The data obtained from 298 patients showed the mean MGD values of 2.0 and 2.4 mGy for the CC and MLO views, respectively [22]. Bahreyni Toossi *et al.* [21] conducted a study on the MGD values arisen from mammographic examination in Khorasan, Iran. They reported that average MGD values per image were 1.11 and 0.88 mGy for the MLO and CC views, respectively [21]. The MGD results in the present

study compared to results from other studies and reports in this field are summarized in Table 2. Notably, the difference in the MGD values from the mammographic examination, which has been reported in several other studies, can be attributed to the differences in applied technical conditions. Additionally, the uncertainty in breast glandular content classification, different CBT values, and different conversion factors applied in the MGD estimation. The local DRL from mammography examinations for Kashan obtained 1.91 mGy for digital and 1.32 mGy for analog mammography, with an overall mean value of 1.72 mGy. The DRL is usually used to control the exposure to ionizing radiation at a level proportionate to the clinical aim of a medical imaging task [36, 37]. This quantity indicates the third-quartile/median value from the distribution of ionizing radiation exposure delivered to patients for a specific imaging procedure [38, 39]. In details, the national DRL value can be defined as the third quartile of the median values of the studied parameters, for instance, the MGD obtained from each healthcare facility. In addition, a local DRL value can be obtained by using an alternative method: for a reasonable number of X-ray rooms (e.g., 10–20), this quantity can be obtained from the third quartile of the distribution, and it can be specified as the median of the distribution for a single facility or smaller numbers of X-ray rooms [40]. Based on the above description, the local DRL reported in this study was established as the overall median MGD value. Table 3 presented our obtained local DRL compared to values reported in previous studies. It was found that the DRL value obtained from the current study is lower than those of Young *et al.* [41], Smans *et al.* [42], Ciraj-Bjelac *et al.* [12], and Baldelli *et al.* [43], but it was higher than that of Bahreyni Toossi *et al.* [21] study.

Table 2. MGD values reported by several studies

Author and Year	Country	Mean MGD (mGy) for CC view	Mean MGD (mGy) for MLO view
Alizadeh Riabi *et al.* [2010] [22]	Iran- Tabriz	2	2.4
Tsapaki *et al.* [2008] [20]	Greece	1.2	1.5
Bahreyni Toossi *et al.* [2013] [21]	Iran- Khorasan	0.88	1.11
Ciraj-Bjelac *et al.* [2010] [12]	Serbia	1.9	1.9
Moran *et al.* [2005] [30]	Spain	1.8	1.95
Bouzarjomehri *et al.* [2006] [23]	Iran	1.20	1.63
Avramova *et al.* [2008] [31]	Bulgaria	2.05	2.4
Bor *et al.* [2008] [32]	Turkey	1.65 (RCC)	-
Suad *et al.* [2013] [33]	Bosnia and Herzegovina	0.78	0.94
Mehnati *et al.* [2014] [34]	Iran	1.73	2.02
Paknya *et al.* [2011] [35]	Iran	1.17	1.17
Current study	Iran, Kashan	2.51 ± 1.53	2.95 ± 1.89

Table 3. The obtained local DRL compared to values reported by previous studies

Author and Year	Country/Region	DRL Value (mGy)
Young *et al.* [2002] [41]	United Kingdom	3.5
Smans *et al.* [2005] [42]	Belgium	2.37
Ciraj-Bjelac *et al.* [2010] [12]	Serbia	2.1
Baldelli *et al.* [2011] [43]	Ireland	1.75
Bahreyni Toossi *et al.* [2013] [21]	Iran- Khorasan Provinc	1.33
Current study	Iran, Kashan	1.72

4. Conclusion

Our results showed that the mean MGD values per mammography exposure were 2.51 ± 1.53 mGy for the CC, and 2.95 ± 1.89 mGy for the MLO views, which are in the range of the other reports from previous studies. Furthermore, considering the European guidelines for quality assurance in breast cancer screening and diagnosis, the obtained DRL of 1.72 mGy (1.91 mGy for digital and 1.32 mGy for analog mammography) was less than the recommended diagnostic reference dose level of 2.0 mGy.

Acknowledgments

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