Radiation doses and potential cancer risks during mammography procedures at southern Saudi Arabia

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▸ ***Original article***

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ABSTRACT

Background: This study aimed at estimating the mean glandular dose (MGD) and cancer risks during mammography examinations. ***Materials and Methods:*** The patients underwent three projections per breast: using craniocaudal (CC), mediolateral oblique (MLO) and mediolateral (ML) projections in a calibrated digital mammography unit at Najran University Hospital, Najran, Saudi Arabia. A total of 510 mammograms were performed, using the three views per breast. The MGD values were estimated indirectly from the entrance surface air Kerma (ESAK) and half-value layer (HVL) based on the conversion factors reported in the literature. The breast cancer risks were estimated based on the data available in the International Commission on Radiological Protection (ICRP) publication 103. ***Results:*** Mean breast thickness of 4.4, 5.3 and 5.0 cm and MGD of 1.01±0.3, 1.09±0.2 and 1.09±0.2 mGy were noted for CC, MLO, and ML views, respectively. A significant correlation has been observed between breast thickness and MGD as well as applied exposure factors. Moreover, the results indicated that the cancer risk per projection was estimated to be 178 $x10^6$, which can be significant during repeated exposure to these examinations. ***Conclusion:*** The comparison with the published data of the countries reported in this study revealed that the mean MGD is comparable or less compared to previous studies. However, young patients required a precise justification. The results are useful for national and professional organisations. Moreover, the results of MGD in Najran could be a helpful guide to the local authorities.

Keywords: *MGD, ESAK, mammography, cancer risks.*

INTRODUCTION

Breast cancer is considered the most common cancer in women around the world (1). In 2018, the World Health Organization (WHO) estimated that 627,000 women died from breast cancer which accounts for almost 15% of all cancer deaths among women (2). Further, previous studies have indicated that early detection by mammography screening can significantly reduce deaths from breast cancer (3, 4). It is worth noted that the women undergoing screening mammography do not complain of any symptoms (5). However, mammograms are not used only to detect early breast cancer in women, but can also be used to diagnose and detect breast diseases such as pain, lump, nipple discharge or skin dimpling (6). Regarding screening mammography, the WHO and United State Preventive Services Task Force (USPSTF) recommended biennial examining the breast for women aged 50-69 years and 50-74 years, respectively (2,7). Commonly the screening examinations are performed using craniocaudal (CC) and mediolateral oblique (MLO) projections (5). However, these examinations should include both breasts. Furthermore, and given the difficulties that a radiologist may encounter in detecting some breast cancers, additional projections may be required to imaging breast tissue more effectively. Accordingly, the diagnostic mammogram can include full MLO, CC, and/or supplemental views to evaluate an area of clinical or imaging concern.

As previously mentioned, mammograms can use for early detection of breast cancer. However, these procedures can also include breast self-examination and/or clinical breast examination [8,9]. Nevertheless, mammography is considered the preferred method for screening of breast cancer compared with other medical procedures [10]. But the risk of developing cancer, associated with breast dose, constitutes a concern for the medical community. A previous study indicated that the radiation dose is around 3.0 mSv per procedure [11]. Further, the mammary gland is highly radio-sensitive, especially following exposures at a young age. Therefore, the absorbed doses from repeated mammography procedures may increase the risk of breast cancer [12]. As a result, the amount of radiation doses associated with X-ray mammography has been an important research topic for several years [13-19].

Generally, the amount of radiation absorbed by the breast tissues and the related health risks are estimated using the mean glandular dose (MGD) [20]. The MGD can be measured directly using mammographic phantom and thermoluminescent dosimeters [19]. Also, it can be calculated indirectly from the entrance surface air Kerma (ESAK) and the conversion coefficient derived from Monte Carlo simulations [13, 20]. Different conversion coefficients, reported in previous studies [17, 21], can be used to extrapolated MGD values. These coefficients depend on the composition and breast thickness, tube voltage (kVp), filtration, target material and breast parenchymal pattern.

About 8,000 women are subjected to breast diagnosis annually in Saudi Arabia [22]. The Saudi Cancer Registry (SCR) pointed out that the most common cancer among Saudi nationals is breast cancer and contributes to 30.1% of all cancer incidences among women [23]. A previous study investigated the data provided by SCR in the period between 1990 and 2000 [24]. The study indicated that the distribution of breast cancer cases was 34.8% at 30-49 years cases in 1990 in comparison with 21.5% in the years 1994-2000. Furthermore, recent studies in Saudi Arabia indicated that there is a significant increase in the number of breast cancer cases, which occur at an earlier age than in Western countries [22-24]. These figures expected to increase due to several reasons: lifestyle changes, and the increase in the number of population and elderly.

As previously mentioned, some cases require the use of additional views due to the difficulty of detecting some types of breast cancer. Using these views is attributed to the radiologists need to compare the images of both breasts, which may look different for each woman compared to the size of a natural breast. Likewise, affected women can be exposed either due to diagnosis or treatment to multiple radiation doses. Hence, this may also significantly increase the risk of radiation to some sensitive organs or tissues [20, 25]. As reported in a previous study, the delivery of ten mGy to a female, under the age of 55 years, can notably increase the risk of induction of breast cancer for up to 14% [26]. Accordingly, it is essential to reduce the exposure to the radiation in mammography examinations to the lowest level. In addition, a reasonable assessment of the quality of the mammogram is compulsory to strike a balance between benefits and the risks of patient exposure. In order to enhance the reduction of mammography radiation dose, the present study aims to evaluate the MGD and the probability of the occurrence of breast cancer for patients undergoing mammography examinations in southern Saudi Arabia.

MATERIALS AND METHODS

The Scientific Research Ethics Committee ethically cleared this study at Najran University (Ref. MID-17-003EC). Further, written informed consents were obtained from all individuals included in this study before the commencement of data collection. This study included 85 patients who underwent mammography examinations in the radiology department of Najran University Hospital (NUH) in Najran, Saudi Arabia. A total of 510 mammograms requested by doctors were studied. Patients experienced various symptoms such as pain, lump and/or nipple discharge. However, all of

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them are underwent mammograms after their clinical conditions were medically justified. For each patient, the demographic data, exposure parameters [kVp, tube current (mAs), and exposure time (T)], and X-ray views were recorded. Based on our local protocol for abnormality cases, the patients underwent three projections for each breast: CC, MLO—and mediolateral (ML) projections.

Mammography unit

All breast examinations were performed in this study using a digital mammography unit (Mammomat Novation^{DR}, Siemens, Erlangen, Germany). This unit equipped with a pivoting bucky, that able to rapidly switch between a digital full-field detector and a digital spot detector or two different film cassettes. Furthermore, the unit included an automatic exposure control (AEC) system. This unit was consist of amorphous selenium (Se) direct conversion flat panel detector with a size of 24 cm × 29 cm that allows imaging of almost all breast sizes. While, the tube head is consist of three anode/filter combinations: molybdenum/ molybdenum, molybdenum/rhodium and Tungsten/rhodium.

Patient position and breast thickness

In both screening views CC and MLO, the positioning was performed by return the breast to its natural anatomical position. The axis of the nipple was perpendicular to the chest wall, to maximise the view of breast tissue and to avoid tissue superimposition and motion artefact. The MLO view was taken from the centre of the chest outward from an angled view. The pectoral muscle was depicted obliquely from above and visible down to the level of the nipple. The CC view was taken from above the breast to depict the entire breast parenchyma. Regarding the ML view, the compression plate was positioned on the lateral side of the breast, and later the x-ray was directed from the lateral to medial direction. For all procedures, the distance from the target to the skin of the patients was 65 cm. Parameters of exposure were selected based on the breast thickness.

Dose calculation and cancer risk estimation

ESAK is the most common quantity to evaluate patient doses in mammography. Furthermore, choosing of ESAK will enable easy comparison with previous studies. Accordingly, the patient doses, in terms of ESAK, was determined per projection for each procedure. Subsequently, the half-value layer (HVL) based on the range of kVp used was selected. Finally, to estimate the MGD for each view, the SPSS version 14 (SPSS Inc, Chicago, IL) was used to extract the appropriate ESAK to the MGD convertor (g) using the conversion factors provided by Dance et al. [21]. The conversion factor to MGD used with 50% granularity. These conversion factors used in reference to beam filter, HVL, breast thickness and composition. Thus, the MGD (D_g) value was calculated in this study using equation (1).

$$D_g = ESAK \times g \times s \times c \quad (1)$$

where g is ESAK conversion factor related to HVL and breast thickness that calculated using Monte Carlo simulation, c is a factor that used to fit the difference in the breast composition and s factor used to adjust the variation in the X-ray spectrum.

The probability of developing cancer depends on the amount of effective dose, which can be calculated by multiplying organs equivalent doses by tissue-weighting factors. Consequently, the risk of cancer was determined following mammography using the mean equivalent dose and radio-sensitivities factors. Based on the data reported in the International Commission on Radiological Protection (ICRP) publication 103, the risk of malignant tumour represents a 5.5% chance of developing cancer [20]. Accordingly, the probability of cancer per procedure was estimated using the risk coefficient of 116×10^{-4} Sv^{-1} for breast cancer due to radiation [20].

RESULTS

A total of 510 mammograms were performed in the present study using three views per

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breast. The patients' ages ranged from 27 to 71 years, with an average of 43.4 years. Only 4.5% represented patients ages between 27-30 years, while 27.6, 43.3, 21.1 and 3.5% were seen for subsequent decades, respectively. Most of the patients were young, indicating that they are more vulnerable to risk compared to older patients. Tables 1 present the descriptive analysis of the exposure parameters, age, breast thickness, radiation doses (mGy) for all patients. The kVp values applied for all mammography procedures were ranged from 24 to 32. The disparity between these values is attributed to the use of lower tube voltages to diagnose the thinner breasts (<30 mm thick). In contrast, higher tube voltages values were used for denser breasts (>65 mm thick). The range and the mean of the kVp values were comparable with previous studies [17, 27-28]. This method has shown that it may help in decreasing the MGD values for thicker breasts. Figure 1 shows the relationship between kVp and MGD (mGy) values for different breast sizes less than 30 mm thick and over 65 mm thick.

Table 1. Exposure parameters, demographic data and patients doses during mammography.

	Mean and range*	Median	3rd quartiles
kVp	28.9±1.34(24-32)	27	30
mAs	79.5±21.32(27-172)	72	88
T (ms)	575.1± 126.31(437-1243)	501	625
Age (year)	43.4±8.3(27-71)	43	50
Breast thickness (mm)	49.1±10.32(24-76)	47	56
ESAK (mGy)	4.3±0.83(1.5-7.7)	4.7	4
MGD (mGy)	1.1±0.21(0.30-1.9)	1.1	1.1

*Mean ± standard deviation (minimum-maximum)

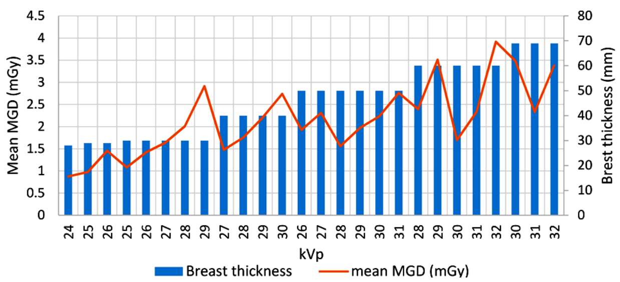

Figure 1. Relationship between kVp and mean MGD (mGy) values for different breast thicknesses.

The mean of breast thickness values for CC, MLO and ML images are 43.5±5, 53.4±11 and 50.2±7 mm, respectively. While the median of breast thickness obtained for all views is 5 cm. The range of the breast thickness (29-76 mm) for MLO views was higher compared with CC and ML views. Among all patients, the mean weight and height values at diagnosis were 155±5 cm and 73.4±1.1 kg. The mean BMI was 30.4±4.3 kg/m^2, ranging from 18.1 to 48.1 kg/m^2. The mean values of MDG (mGy) obtained for CC, MLO and ML projections are 1.01±0.3, 1.09±0.2 and 1.09±0.2, respectively. The relation between exposure parameters and patient doses per projections are shown in table 2. A significant linear correlation was seen between the MGD and mAs ($p<0.01$). Additionally, significant correlations were also seen between the MGD and breast thickness' ($p<0.01$). The probability of induced cancer on account of using mammography was estimated to be 178×10^6.

Table 2. Exposure parameters and patients doses per projections.

	Protections		
	CC*	**MLO***	**ML***
kVp	28.4±1.3 (24.0-31.0)	28.8±1.4 (24.0-32.0)	29.4±1.3 (24.0-32.0)
mA	74.4±17.3 (27.0-172.0)	82.2±19.0 (30.0-139.0)	78.7±20.1 (30.0-146.0)
T (ms)	553±64 (452-984.0)	598±143 (437-1243)	581±94 (437-1243)
Dose (mGy)	1.01±0.3 (0.3-1.7)	1.09±0.2 (0.4-1.8)	1.09±0.2 (0.4-1.9)
Breast thickness (mm)	43.5±5.0 (24.0-63.0)	53.4±11.0 (29.0-76.0)	50.2±7.4 (27.0-69.0)

*Mean ± standard deviation (minimum-maximum).

DISCUSSION

Data across the world indicate a steady increase in the incidence of breast cancer. Accordingly, an assessment of the radiation dose and the estimate of the risk of developing breast cancer are necessary to evaluate justification standards of the procedure primarily based on a risks or benefits analysis. Moreover, the technologists will be able to improve the image quality with minimal

exposure to patients. As previously mentioned in the introduction section, within the routine screening examinations, CC and MLO, are usually used as standard views. However, an additional ML view, for each breast, was used in this study. The difference between the projections is due to the fact that the patients who underwent screening programs do not complain of any symptoms, while the patients included in this study had undergone mammography due to suspected breast cancer.
The ML view is extremely useful because the lateral side of the breast is probably the most common area for pathological changes to occur. Moreover, an ML view may also be beneficial to the radiologist to differentiate the actual lesion from the superposition of glandular tissue. Benefits of an ML view may also include the ability to show a lesion located deep near the chest wall and/or lesion located high in the upper inner quadrant. In other words, the ML view can used to locate a lesion not included in the MLO view or not demonstrate on the CC view but seen on an MLO view. In this study, the MGD for CC, MLO and ML projection was 1.01±0.3, 1.09±0.2 and 1.09±0.2 mGy, respectively (table 2). The patient dose per examination is lower than those reported in England [28], Norway [27], and United States of America (USA), California (CA) [29], comparable to Korea [30] and Canada [11] and higher than results reported in USA, Minnesota [31] with factor up to 1.1 (figure 2). The different between radiographic system and the imaging technique used in this study and other countries may be one of the essential reasons for the variation of patient doses. In addition, some of these studies used the conversion factors reported by Wu *et al.* [21] to calculate the MGD, while other used factors reported by Dance et al. [17]. It is worth mentioning that the conversion factors presented by Dance et al. are 10% lower than ones published by Wu *et al.* [21].

This study showed a correlation between breast thickness and kVp with the MGD. In comparison, a previous study [32] stated that no correlation among breast tissues compressed thickness affected radiation dose (MGD) in projection imaging. However, they reported a significant correlation with 3D imaging. An essential requirement in mammography is to balance between mAs and kVp and radiation dose. Hence, implementing optimisation techniques requires an understanding of the image acquisition process. For example, increasing the kVp value will inevitably increase the penetration capabilities of the X-ray beam. Consequently, this permits lower mAs values to be applied, decreasing patient dose. However, the high-energy X-ray beams cause low image quality. Comparing with conventional radiography, this is no longer the case for digital mammography system. In the digital system, higher kVp values may still present adequate image quality because image contrast depends basically on the signal-to-noise ratio.

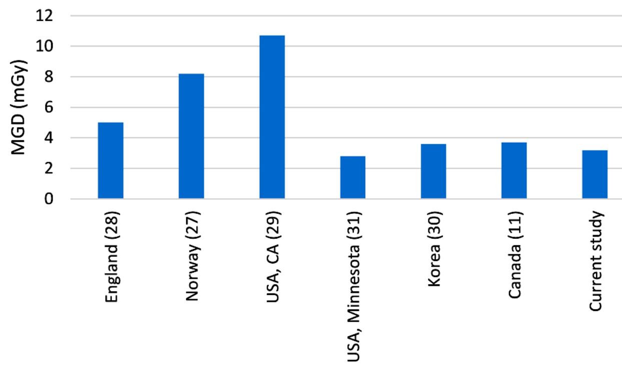

Figure 2. England [28], Norway [27], USA, CA [29], USA, Minnesota [31], Korea [30] and Canada [11].

The results show that there are differences between patient doses examined by the same mammography machine (table 2). The presence of these differences can be attributed to the difference between breast tissues in the patients. The exact amount of cellularity is age-dependent. With an increase in age, the amount of cellularity within the adipose/fatty tissue increases, whereas fibrous tissue decreases [11, 24, 33]. Moreover, the MGD per projection is likewise less than the maximum dose reported by Mammography Quality Standards Act (MQSA) regulations or Food and Drug Administration (3.0 mGy for an individual screening view) [34]. One of the principal sources of high radiation dose can be attributed to ethnic origin, which may influence breast thickness and density. Thicker and denser breast are found in North

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America countries compared to Asian [35]. As a result, the variation in MGD found between present study and data provided by Kruger and Schueler from the USA, Minnesota [31] or others (figure 2) is expected, because the attenuation of the radiation beam in mammography relies on breast size and density. For example, Kruger and Schuyler pointed out that the median of MGD is 2.6 mGy for breast thicknesses ranging between 1.3 and 10.7 cm. However, the maximum breast thickness reported in this study is 7.6 cm.

In a previous study, it was reported that attempts to reduce the mortality because of radiation-induced cancer, may exceed the reduction in deaths by breast tumours due to screening programs [28]. The cancer risk because of mammography in this study was estimated to be two cancer cases per 10^4 examinations per breast. However, detecting cancer or evaluating other breast diseases includes using different imaging modalities. Figure 3 shows the average equivalent breast doses for patients who undergo various imaging examinations. Such examinations include computed tomography (CT) Pulmonary Angiography [36], CT chest [37], Breast-specific gamma imaging (BSGI) [38], Ventilation/Perfusion SPECT [39], Dedicated breast CT [40], mammography [38] and positron emission mammography (PEM) [38]. The estimated breast doses during imaging modalities that based on radionuclides, such as PEM and single-photon emission computed tomography (SPECT), is less than the group of dedicated breast CT and mammography. On the other hand, figure 3 includes some imaging modalities such as CT pulmonary angiography and CT chest, where the breast is not the organ of concern in these examinations. However, the breast doses in these modalities are range from 9.3 to 20.0 mGy. Thus, there must be an accurate justification for using these modalities to avoid breast cancer.

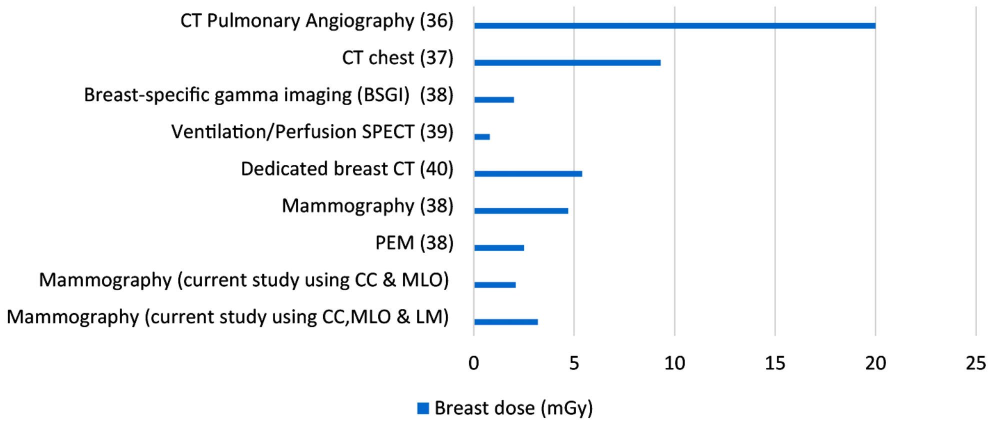

Figure 3. Breast doses using different imaging modalities [36-40].

CONCLUSION

There is a statistically significant relationship at the level of significance or less between the MGD and mAs and breast thickness ($p < 0.01$). The risk of developing breast cancer from mammography in this study is notably low, but repeated exposure will increase the risk of developing breast cancer to a substantial stage. Therefore, there should be a careful justification, especially for young patients. MGDs are comparable or less as compared to preceding studies. Establishment of a diagnostic reference level in Saudi Arabia for mammography will minimise the malignancy risk due to radiation to its lowest possible value.

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