

Assessment of Breast Doses in Mammography Screening

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ABSTRACT

Thermoluminescent dosimeters (TLD-100H) were in use for the assessment of average glandular dose to breast in mammography screening with GE machine, King Abdul Aziz University Hospital for 45 mm breast compressed thickness, 26 kVp, 100 mAs and Mo/Mo target/filter combination. Reader's calibration factor for the TLDs was generated with the same exposure parameters using RadCal mammo ionization chamber as reference. The calibration factor was reproduced within 3% standard deviation. Several sets of selected TLD-100H placing in different configurations were exposed to X-ray beam under identical exposure condition as it was used for generation of calibration factor. The entrance surface doses were calculated by using the measured net TL-response and the calibration factor. Thereafter, the average glandular doses (AGD) were calculated. The measured average entrance surface dose (AGD) at the reference position (6 cm laterally centered from the chest edge wall) was 7.704 mGy with less than 2% standard deviation. The calculated average glandular dose to the breast at the reference location has been found to be 1.429 ± 0.037 mGy.

Key words: TL-dosimetry, mammography, breast screening, entrance surface dose and average glandular dose.

INTRODUCTION

There is a significant risk of radiation induced carcinogenesis associated with the X-ray examinations of the female breast, particularly to the radiosensitive glandular tissues in the breast. Diagnostic exposure for medical examinations are based on the clinical needs as well as justified for the sake of benefits of accurate diagnosis of possible disease conditions. In practice doses to a particular target organs varies depending on specific machine parameters and study technique involving frequent over exposure than clinical needs. As such,

standardization of radiation dose is required for a number of typical diagnostic medical procedures. Mammography is one of the widely used procedures for breast screening of small malignant lesions in the female breast, resulting significant reduction of breast cancer mortality, particularly in older women (1-4). Breast cancer is considered as the second highest cause of cancer deaths among the female patients in many countries. Age is the most important single risk factor in the development of breast cancer. Breast cancer incidence increases dramatically as a function of patient age (5-7). Mean glandular measurements results on women of age group between 49-65 years demonstrated expected increase of dose (1 – 6 mGy) with breast thickness varied from 2 to 11 cm (8).

Statistics in mammography indicates that the incidence of breast cancer per 100,000 women increased by approximately 4% during the 1980s and leveled off to about 100 cases per 10,000 women in 1990s. The reported death rates from breast cancer also declined significantly between 1992 and 1996. Medical doctors consider the reduction in breast cancer death via earlier detection and more effective treatment (9). In 2001, World Health Organization (WHO) predicted more than 1.2 million new breast cancer cases globally, while in the USA, both the American Cancer Society and the National Cancer Institute estimated approximately 192,200 cases of invasive breast cancer. The national diagnostic reference level (NDRL) of 3.5 mGy for 55 mm thick breasts has been proposed by UK study in mammography screening as an appropriate value, to identify systems giving unusually high doses, with

3.5% of systems exceeding this level (10, 11). The role of dosimetric methods and influence of exposure parameters on the establishment of reference doses in mammography has been extensively studied by Zoetelief et al (12). They concluded that TLD measurements with 45 mm PMMA phantom representing 50 mm compressed breast thickness are the most reasonable approach for AGD estimation. Estimation of Patient average glandular dose to breast in mammography coupling with quantitative consideration of variables that affect the dose are compressed breast thickness, tube potential, tube loading, target/filter combination, magnification and beam collimation. Among them having the greatest effect are breast thickness and magnification. As for example, 8 cm breast receives about four times the mean tissue dose of 3.5 cm breast (13). The incident air kerma during mammography procedures were assessed using standard breast phantom and patient AGD at different institutes of Brazil by Khoury et al (14). This method involves recording the patient exposure parameters; kVp, mAs, target/filter combination, and the incident air kerma measured with ionization chamber. The results showed a wide variation in the measured air kerma among the institutes (8.5 mGy to 18.2 mGy). The results of patients' AGD values ranged from 0.23 mGy to 7.46 mGy per film and AGD values per women were found between 8.23 and 40.6 mGy in private hospitals, and 1.5 to 18.8 mGy in public hospitals. Bulling and Nicoll (15) surveyed breast dose for a screening program in New Zealand. They found that while mean glandular dose from individual exposures ranged from 0.7-8.5 mGy, the total mean glandular dose per patient ranged from 4 to 29 mGy due to multiple films being taken. Thilander-Klang et al found that substantial dose reduction up to 50% could be made with correct choice of X-ray spectrum maintaining good image quality (16).

An early detection by using modern mammography systems with automatic beam quality selection and

alternative target filter combinations, introduced about 15% reduction in average received dose and up to 50% reduction in received doses to large breasts, resulting decrease of mortality rate significantly (17, 18). The AGD to glandular tissues in female breast is considered as the best indicator for the estimation of potential cancer risk from mammographic screening (19, 20). A significant increase of AGD in the breast screening over the limit usually associates greater risk. AGD is derived from measurement of the entrance surface air kerma (ESAK), or in some literatures defined as entrance surface dose (ESD), half-value layer (HVL) of the X-ray beam and the breast compressed thickness. Assumption for conversion factor CDG50,Ki,PMMA (mGy/mGy) is used to calculate the average glandular dose (AGD) in different breast thicknesses. The assumption is based on the breast of composition 50% fat and 50% glandular tissue (3). In the recent years, these conversion factors have been extended to a larger interval of breast thicknesses and to account for other breast compositions and X-ray spectra (7, 21). Individual patient doses to breast glandular tissues are not possible to measure directly in mammography breast screening. However, several types of dosimeters are in use for breast dosimetry without much interfering diagnostic image quality. Thermoluminescent dosimeters (TLD), placed on the entrance surface of the breast, is considered as one of the tools of practical methodology in breast dosimetry. The present work has been conducted to justify the use of TL-dosimetry for the assessment of AGD to the breast in mammography screening. The research works have been accomplished using the X-ray machine dedicated for mammography screening in the Radiology Department, King Abdulaziz University Hospital, Jeddah.

MATERIALS AND

METHODS Calibration

All the experimental measurements were done using GE Senograph 2000D Mammography unit in King

Abdul Aziz University Hospital, Jeddah. The X-ray beam from 26 kVp, 100 mAs and Mo/Mo target/filter combination has been used for TLD calibration in terms of air kerma free in air. Selection of TL-dosimeters involved several steps in the processes, such as sensitivity of the group of TLDs on background response, annealing at 240 °C for ten minutes, cooling to room temperature, reading out TL background response of each dosimeter in a single session, irradiating the selected chips with a fixed quantity of radiation from ⁹⁰Sr/⁹⁰Y source. The irradiated chips were stored in a shielded container for overnight and thereafter all the TLD were read out with HARSHAW 4500 TLD reader in one session. Groups of TLD-100H chips having response variation within 2.5% standard deviation were selected for calibration. The calibration of the selected TLD-100H followed two step procedures. The first step involved, recording the exposure parameters and irradiation conditions (tube potential, tube loading, target/filtration combination) and measurement of Air kerma at the entrance surface of the breast for a selected projection. One set of five unexposed TLD-100H dosimeters were placed over 45 mm mammo phantom (bolus) at laterally centered 60 mm from the chest edge wall. TL dosimeters were irradiated with tube potential of 26 kVp, tube loading 100 mAs and Mo/Mo target/filter combination, shown in figure 1. The TLD response (nC) of each dosimeter was readout using HARSHAW 4500 reader. The TL response was subjected to correction for background, obtained from the average response of control dosimeters, and for sensitivity of each dosimeter (Element Correction Co-efficient). The second step was to measure exposure with SSDL level RadCal mammo ionization chamber under identical exposure condition as it was used for irradiation of TLD dosimeters. Placement of ionization chamber has been shown in Figure 2.

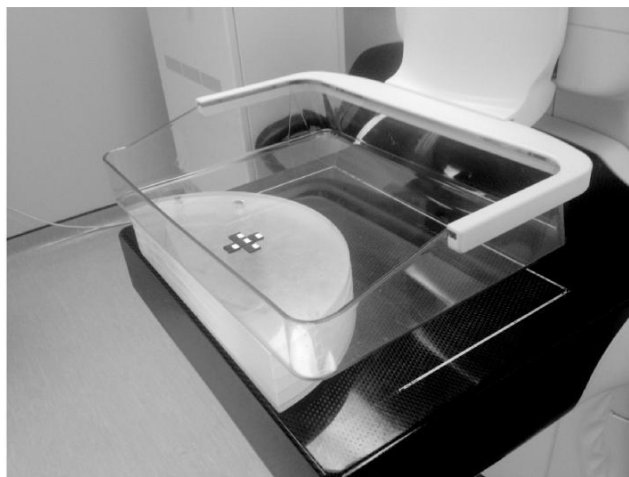


Figure 1. TLD set up for calibration



Figure 2. Placement of ionization for calibration experiment

The calibration factor has been generated using the following equation:

$$CF \text{ (nC/mGy)} = \text{TLD response (nC)} / \text{Ionization chamber reading (mGy)} \quad (i)$$

Where, CF is calibration factor for the measurement condition, nC is the average of net response (corrected for ECC) of TLDs, and Dose (mGy) is from ionization chamber readings.

Average Glandular Dose (AGD)

Four sets of unexposed new TLD-100H were used for the measurement of incident air kerma to the surface of breast target in order to calculate AGD to representative breast glandular tissues. The TL

dosimeters were placed over 45 mm thick PMMA mammo phantom, representing 50 mm breast thickness, in different configurations. The TLDs placed at laterally centered position of 60 mm from the chest edge wall is considered as the reference location. They are shown in figure 3 (a, b, c, d). Each position over the phantom was grouped as the size of TLD before the insertions of the chips. Each set of TLDs was irradiated separately under identical exposure condition.

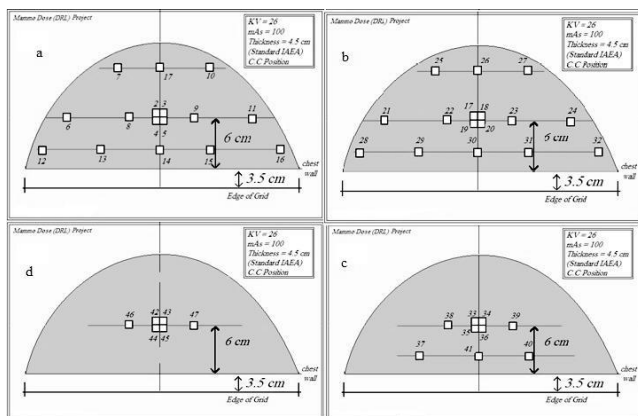


Figure 3. TLD placement during AGD measurement

Each set of TLDs was irradiated using tube potential (26 kVp), tube loading (100 mAs) with Mo/Mo target/filter combinations. Thereafter, TLDs were read out. AGD was calculated using the following equation.

$$D_G = C_{DG50,Ki,PMMA} \times S \times K_i \dots (ii) \quad [3]$$

Where, D_G is the dose to glandular tissue, $C_{DG50,Ki,PMMA}$ (mGy/mGy) is the conversion coefficient for the measured half value layer (HVL) and the standard breast of 50 mm thickness with 50% glandularity (assumed) that is simulated by the 45 mm PMMA phantom, is spectral correction factor for the selected target/filter combination and K_i is the incident air kerma. The incident air kerma has been calculated using the following equation:

$$K_i = \frac{Net\ Dose\ (mGy)}{B} \dots (iii)$$

Where, $Net\ Dose\ (mGy)$ is the calculated value from TLD readings, and B is the backscatter correction

factor for mammographic beam qualities as a function of HVL. The values of $C_{DG50,Ki,PMMA}$, B and S were taken from reference (3). Wherever, necessary $C_{DG50,Ki,PMMA}$ and B value was interpolated.

RESULTS

The calculated calibration factor was 1208 nC/mGy with ~ 3% standard deviation. The measured entrance surface dose to 45 mm breast compressed thickness with X-ray beam generated from 26 kVp, 100 mAs and Mo/Mo target/filter combination has been presented in Table 1. The entrance surface doses (ESD) at different position of breast phantom have been displayed graphically in Figures 4 -7.

Table 1. Measured values of entrance surface dose (ESD) using four sets of TLDs

TLD setup exp a		TLD setup exp b		TLD setup exp c		TLD setup exp d	
TL D No.	ESD (mG y)	TLD No.	ESD (mG y)	TL D No.	ESD (mG y)	TL D No.	ESD (mG y)
1	7.52	17	7.73	33	7.73	42	7.73
2	7.44	18	8.06	34	8.06	43	8.06
3	7.52	19	8.11	35	8.11	44	8.11
4	7.88	20	8.09	36	8.09	45	8.09
5	7.26	21	8.31	37	8.31	46	8.31
6	7.95	22	8.05	38	8.05	47	8.05
7	8.21	23	8.13	39	8.13		
8	7.53	24	7.65	40	7.65		
9	7.26	25	7.26	41	7.26		
10	7.02	26	7.6				
11	7.51	27	7.59				
12	8.47	28	8.16				
13	8.65	29	8.04				
14	8.47	30	8.85				
15	8.37	31	7.98				
16	7.16	32	7.76				

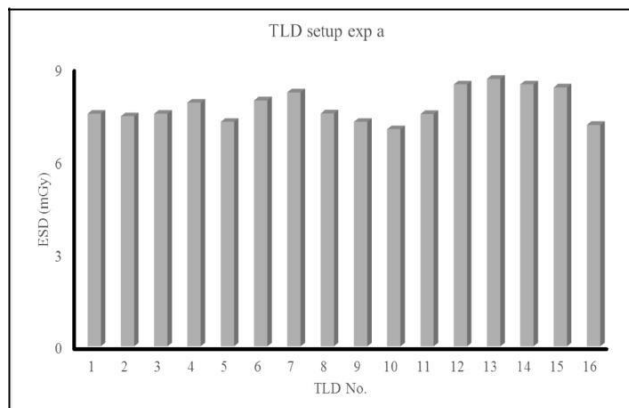


Figure 4. Entrance surface dose measured with experiment 'a'

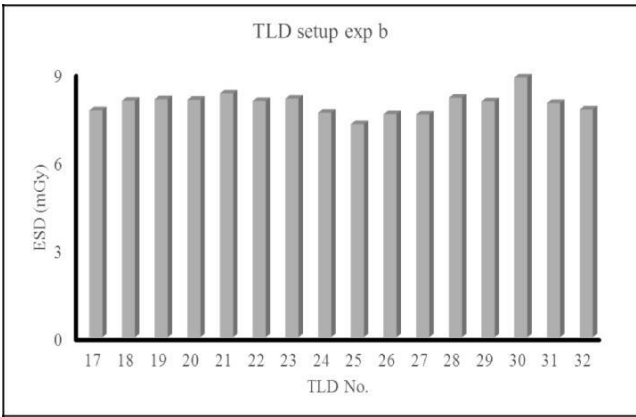


Figure 5. Entrance surface dose measured with experiment 'b'

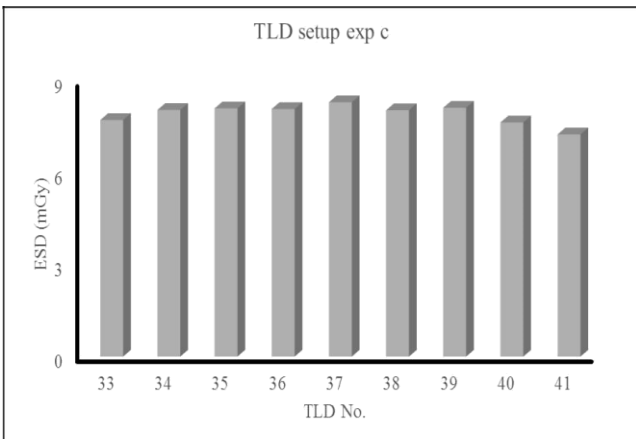


Figure 6. Entrance surface dose measured with experiment 'c'

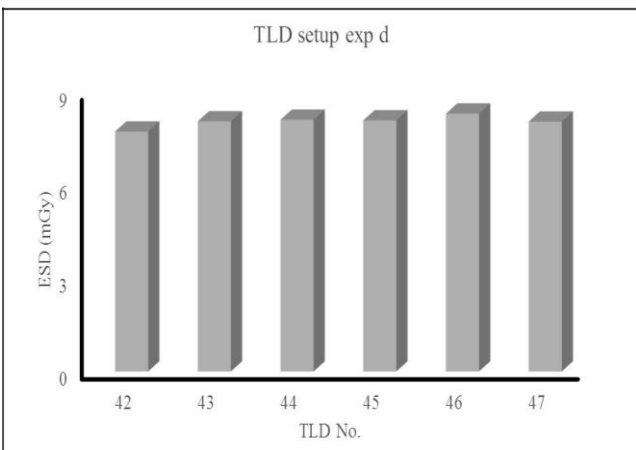


Figure 7. Entrance surface dose measured with experiment 'd'

The Table 2 reads the calculated average glandular dose (AGD) corresponding to the use of different sets of dosimeters, placed with various configurations on the surface of the phantom. Figures 8-11 demonstrate the relative variation of AGD to the breast depending on the sites in the breast.

Table 2. The calculated values of average glandular dose (AGD) to the representative breast

TLD setup exp a		TLD setup exp b		TLD setup exp c		TLD setup exp d	
TLD No.	AGD (mGy)	TLD No.	AGD (mGy)	TLD No.	AGD (mGy)	TLD No.	AGD (mGy)
1	1.361	17	1.399	33	1.399	42	1.399
2	1.347	18	1.459	34	1.459	43	1.459
3	1.361	19	1.468	35	1.468	44	1.468
4	1.426	20	1.464	36	1.464	45	1.464
5	1.314	21	1.504	37	1.504	46	1.504
6	1.439	22	1.457	38	1.457	47	1.457
7	1.486	23	1.472	39	1.472		
8	1.363	24	1.385	40	1.385		
9	1.314	25	1.314	41	1.314		
10	1.271	26	1.376				
11	1.359	27	1.374				
12	1.533	28	1.477				
13	1.566	29	1.455				
14	1.533	30	1.602				
15	1.515	31	1.445				
16	1.296	32	1.405				

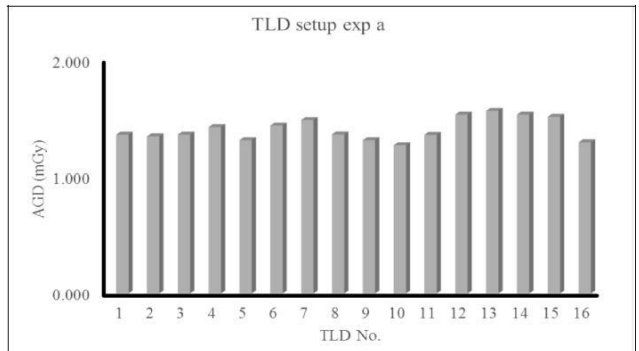


Figure 8. Variation of calculated average glandular dose to the breast

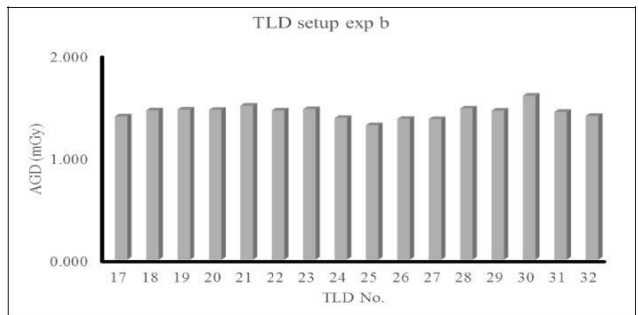


Figure 9. Variation of calculated average glandular dose to the breast

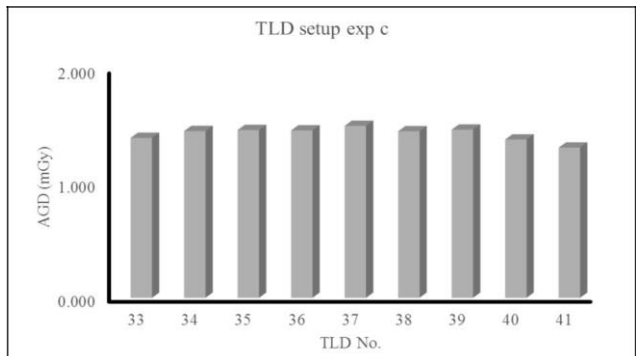


Figure 10. Variation of calculated average glandular dose to the breast

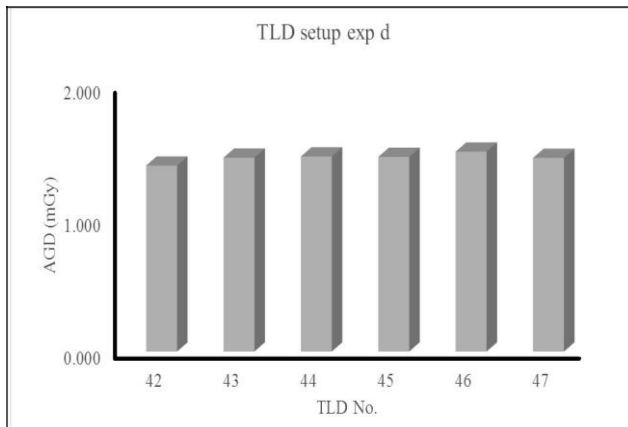


Figure 11. Variation of calculated average glandular dose to the breast DISCUSSION

The set of four TLDs placed at the center (laterally 6 cm from chest wall edge) has been considered as the reference point. The average of the AGDs calculated from ESD values at this location is supposed to be the reference dose of this work. The quoted average glandular dose to the breast refers to the average of the AGD values, calculated by using the ESDs at this site with respect to four sets of TLDs. The average value of entrance surface dose (ESD) has been obtained as 7.704 mGy with less than 2% standard deviation. The corresponding average glandular dose has been calculated to be 1.429 ± 0.037 mGy. There are other influence quantities such as back scatter factor, uncertainty in conversion coefficient, etc. Combining all the sources of errors in quadrature and the value of expanded uncertainty of measurement is between 8% and 14%, considered as acceptable code of practice (3). Of them TLD measurements propagate an error up to 5%. Zoetelief et al (12) recommended 1.6 mGy AGD as the dose reference level for standard 45 mm PMMA phantom. D.R. Dance et al (6) quoted the average glandular dose of 1.2 ± 0.5 mGy for the range of breast thickness 50 ± 3 mm from the work of Thilander et al (16). Assiamah et al (22) reported 1.45 ± 0.29 mGy AGD value obtained from direct measurement of incident air kerma on 40 mm PMMA thickness using 26 kVp beam. D. Bor et al (21) reported 1.34 mGy and

1.3 mGy for 47.4 mm and 47.7 mm breast thickness, respectively using 27 kVp Mo/Mo target/filter beam quality. The AGD value of 1.429 mGy obtained in the present work fairly falls within the range compared to the results of the above mentioned data.

CONCLUSION AND RECOMMENDATION

TL-dosimetry appears to be a reliable technique for the quality assurance in the assessment of average glandular doses to the breasts in mammography screening. The research work reported here represent measurement with one particular mammography machine with a fixed set up of exposure parameters, and breast compressed thickness. The obtained AGD value not necessary represents the dose reference level (DRL) in mammography screening. However, the calculated AGD to representative breast thickness of 50 mm without compression obtained in this work may be considered as a baseline for future extension of this kind of research works at different mammography machine in other hospitals using both TLD and optically stimulated luminescence (OSL) nano Dot dosimeters.

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