Absorbed dose measurements in Mammography using Monte Carlo method and ZrO_2+PTFE dosimeters

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Abstract

Mammography test is a central tool for breast cancer diagnostic. In addition, programs are conducted periodically to detect the asymptomatic women in certain age groups; these programs have shown a reduction on breast cancer mortality. Early detection of breast cancer is achieved through a mammography, which contrasts the glandular and adipose tissue with a probable calcification. The parameters used for mammography are based on the thickness and density of the breast, their values depend on the voltage, current, focal spot and anode-filter combination. To achieve an image clear and a minimum dose must be chosen appropriate irradiation conditions. Risk associated with mammography should not be ignored. This study was performed in the General Hospital No. 1 IMSS Zacatecas. Was used a glucose phantom and measured air Kerma at the entrance of the breast that was calculated using Monte Carlo methods and ZrO_2+PTFE thermoluminescent dosimeters (TLD), this calculation was completed with calculating the absorbed dose.

Keywords: Mammography, absorbed dose, dosimetry.

INTRODUCTION

Often, X rays are used to obtain radiographys of different body parts. Particularly, X rays are used for mammography, aimed at timely detection of breast cancer [1].

Worldwide, breast cancer is one of the most likely malignancy among women. In the UK, mortality from breast cancer is 39.8% per 100000 women older than 25 years, while in the U.S. this rate is 32%, for case of Mexico this value is greater than 15 % [2]. Nationally the highest rate mortality from breast cancer is 30.5% and 26.3% and is presented in the states of Baja California Sur and Jalisco, respectively. The states with the lowest index are Zacatecas, Yucatan and Chiapas with rates of 10.81%, 10.5% and 10% respectively [3]. The patients community of General Hospital No. 1 IMSS Zacatecas has presented during the years 2006, 2007 and 2008, an increase in mammography where it has detected a higher frequency of benign lesions classified as birad 2 (*Breast Imaging Report and Database System)*; this type of injury represents a risk of subsequent breast cancer [4].

Mammography studies should be conducted under the principles of radiation protection. To maintain the values risk-benefit is necessary to have values appropriate references of the dose absorbed by the breast when patient is subjected to mammography studies [5]. One of these reference values is the average glandular (DGM), established by the International Commission on Radiological Protection (ICRP), Because without the standards proper radiation safety a test would cause harm stochastic at patient [6]. The International Commission on Radiological Protection (ICRP) defines the limit value of 3 mGy for DGM [7]. The stochastic damage will depend on the irradiated body, determined by factor weigh tissue (w_T), which in the case of mammary gland is a factor $w_T = 0.05$ [8].

The aim of this work was measure air Kerma at the entrance of breast that was calculated using Monte Carlo methods and ZrO2 + PTFE dosimeters, this calculation was completed by calculating the absorbed dose. The absorbed dose was calculated with the irradiation conditions used in patients of the General Hospital No. 1 IMSS, Zacatecas, Zac.

MATERIALS AND METHODS

This work was conducted in three stages, the first one was to obtain the characteristics of irradiation from 350 patients who were subjected, moreover the characteristics of mammography equipment. The second step was to determine the Kerma in air at the entrance of the breast and absorbed dose using two phantoms and thermoluminescent dosimeters, also was modeled the process of irradiation with Monte Carlo methods. Finally the third stage consisted in comparing the results obtained.

2.1. Patient group

Were analyzed the characteristics with that were irradiated 350 patients who underwent a mammography studies during July to October 2008. This in order to correlate the age and compressed breast thickness of the patient, with voltage, current, combined anode-filter used by the equipment.

In this study, 350 patients were classified by age. The reason is that age group between 43 and 57 years is more prone to breast cancer. In classification by age group was found more frequently in age groups of between 43 to 57 years (54%) and 58 to 72 years (31%). Being the first age group coherent with the group at highest risk at the national level [12]. These age groups represent 85% of population. Then, 85% of these data were classified according to the thickness of compressed breast, in order to determine thicknes distribution. Finally, the distribution of compressed breast thickness was divided on three groups, of each group was found the average thickness. For each group was averaged thickness and the irradiation conditions, these conditions were selected by the mammography device. Finally, the absorbed dose and air kerma on the surface of entry was calculated by the two methods proposed. The irradiation conditions shows in Table I.

Table I. Irradiation parameters for breast

Compressed breast thickness [cm]	Voltage [kV]	Current [mAs]	Anode / Filter
4.2 ± 0.41	25.82 ± 0.66	111.81 ± 19.65	Mo/Mo
5.9 ± 0.65	28.29 ± 2.22	106.5 ± 20.25	Rh/Rh
7.5 ± 1.01	30.4 ± 0.78	100.78 ± 22.24	Rh/Rh

2.2. Features of the mammography equipment

The equipment used was a Senographe 2000D from General Electric, the distance between the focal point and grill is 64 cm. The device uses a exposure system called control automatic exposure (CAE), however the average time of exposure to X-ray beam was 1.5 seconds. Taking combinations of focal point Mo/Mo, Mo/Rh and Rh/Rh. The disc diameter has 70 mm. The Figure 1 shows the mammography equipment.

Figure 1. Mammography equipment, Senographe 2000D.

2.3. Determination of absorbed dose

In this work, aren´t detailed values of air kerma with Monte Carlo methods because the absorbed dose can be estimated directly. In the case of phantoms to estimate the absorbed dose is necessary to obtain the air kerma. The absorbed dose can be obtained by calculations or measurements, the calculations usually require more data in an appropriate model to calculate these values. In the case of measurements to obtain this value is through active and passive detectors, but need know the kerma in air, after can be to estimate the absorbed dose. The value of the absorbed dose was determined using Thermoluminescent dosimeters type ZrO_2 + PTFE [9, 8, 13] and Monte Carlo methods.

In first method, were used two breast phantoms based on 5% dextrose and the use of thermoluminescent dosimeters type ZrO2 + PTFE, where the PTFE is a Teflon-based compound used as a binder and does not disrupt the ability of dosimeter measurement. While the second method involves simulations, using parameters of irradiation. For each of the three groups and the phantoms were modeled in Monte Carlo irradiation conditions.

2.3.1. Thermoluminescent dosimeters type ZrO_2 + PTFE

The risk of induced cancer depends on the dose received, therefore determining the value of the absorbed dose that is applied to patients is an important factor, this criteria must establishes to patient a maximum benefit and dose minimal. When a phantom is used, the dose depends on the density, size and elemental composition of phantom, for this reason are used standardized phantoms that allow doing comparative studies [8].

The purpose of a phantom is to simulate the breast tissue in dosimetric studies. During the experimental phase of this study were used two phantoms of dextrose 5% (H_2O + $C_6H_{12}O_6$). To validate the equivalence of phantom with the female breast was calculated the attenuation coefficients for photons of 1 to 40 keV, which was compared with two commercial phantoms, CRIS and RMI. The calculation was done with the XCOM program of the National Institute of Standards and Technology (NIST) [10].

Once the equivalence is justified, is determined the absorbed dose on glucose phantoms. ZrO_2 + PTFE dosimeters were placed on the entrance and output of surface for the phantom with thickness 3.2 cm. While, in the second phantom of thickness 6.9 cm the dosimeters were placed on entrance, half and output of phantom. The phantoms with dosimeters were exposed the X-ray beam for making the mammography, with witness dosimeters. For each case, the operating characteristics of the equipment are automatically selected. In Figure 2 and 3 is showed diagrams of glucose phantom and the positions where the TLD were placed on the phantoms.

The parameters used in mammography are shown in Table II, the parameters of irradiation were selected automatically by the Senographe 2000D device.

Of each phantom and their respective TLDs was obtained a mammography, Figure 4 shows the mammography with TLDs and phantoms compressed thickness of 6.9 and 3.2 cm. Before exposing the dosimeters were subjected to heat treatment of 300 º C for 30 minutes in order to erase the information. The TLD were read in a Harshaw TLD reader 3500.

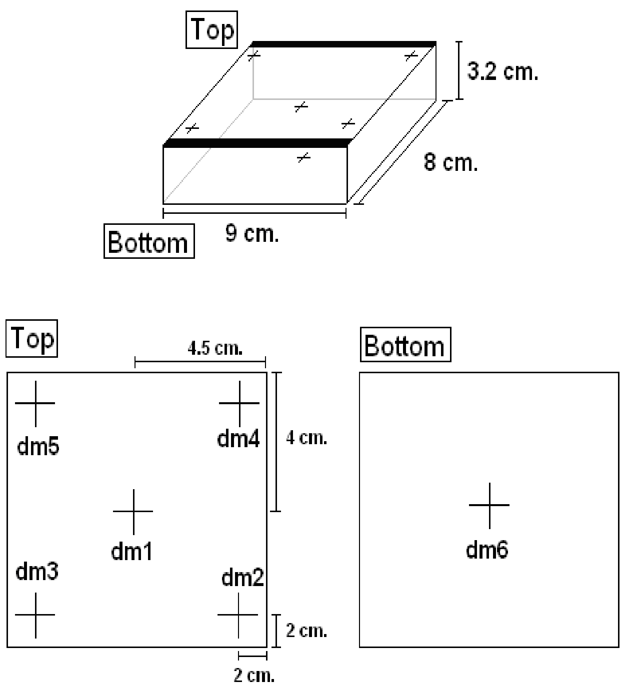

Figure 2. Location of the TLD in the compressed phantom with thickness 3.2 cm.

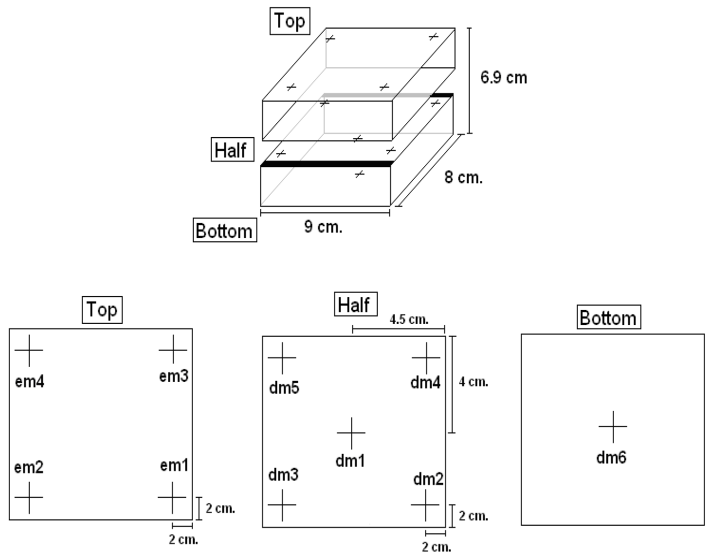

Figure 3. Location of the TLD in the phantom compressed of breast thickness of 6.9 cm.

Table II. Irradiation features for phantoms.

Compressed breast thickness [cm]	Voltage [kV]	Current [mAs]	Anode / Filter
3.2	27	133	Mo/Rh
6.9	32	284	Rh/Rh

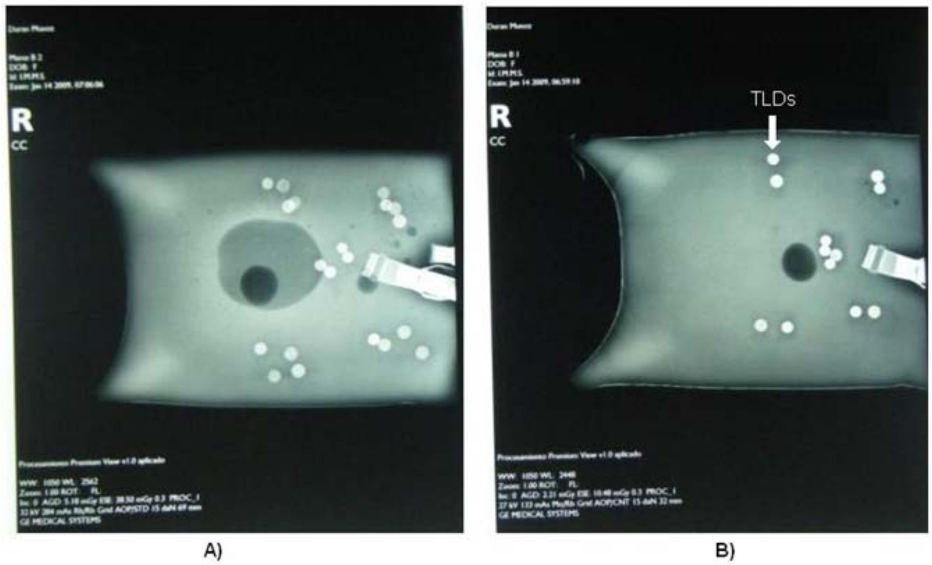

Figure 4. Mammography A) 6.9 cm thickness phantom. B) 3.2 cm thickness phantom.

2.3.2. Monte Carlo methods

In this study, were used Monte Carlo methods, using the MCNPX code. With the aim to model the x rays tube of and used the conditions of irradiation in mammography studies. Monte Carlo methods have a primary processes, which considerer coherent scatter, photoelectric effect, incoherent scatter and pair production. The Monte Carlo method is based in physical process and probability distributions. Particularly, we used to know energy deposition in breast.

The results during experimental phase must be supported by theoretical calculations using techniques such as Monte Carlo simulation. The comparison of the calculations will help to obtain greater robustness in the results. In this work are presented the preliminary results of dosimetry for absorbed dose calculation by Monte Carlo simulation of three representative groups and for two phantoms.

In the Monte Carlo model was considered a source of electrons, an anode of Mo and Rh (70 mm in diameter), Mo and Rh filter (thickness 2 μm) and the breast for each case respectively. Figure 5 shows the model used to determine the dose absorbed. For the physical model was assessed as a source of electrons, which collide with an anode, then generates photons. The number of stories was of 100000 histories.

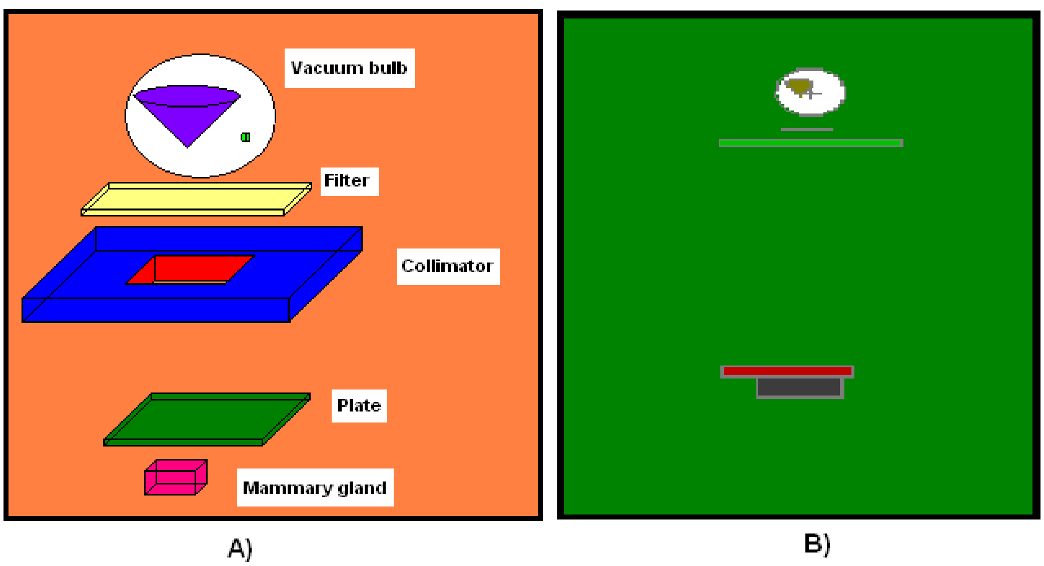

Figure 5. Model used with Monte Carlo methods.

In the model used were changed the conditions of irradiation, depending on thickness as well as for the phantoms. Finally, 5 models were designed, one for each condition. Each iteration took about 28 hours.

3. RESULTS AND DISCUSSION

3.1 Absorbed dose in patients

The three breast thicknesses, wich represent to population analyzed, and the characteristics that were used by device for obtaining a mammography are shown in Table III. The irradiation parameters of Table III are with those commonly radiate the patient.

The values obtained by Monte Carlo methods and mammography equipment are close, which means there aren´t significant differences. Hence, both estimates have a high degree of reliability because they are frequently used. The values issued by Senographe increased when breast thickness are increasing, which is consistent because this will help the clarity of the image. The dose values were higher for larger thicknesses, this is because the quality of the image that depends on the thickness breast.

Table III. Absorbed dose for breast

Compressed breast thickness [cm]	Monte Carlo [mGy]	Senographe [mGy]
4.2 ± 0.41	2.09 ± 0.06	1.95 ± 0.24
5.9 ± 0.65	1.93 ± 0.05	2.24 ± 0.35
7.5 ± 1.01	2.14 ± 0.05	2.43 ± 0.54

3.2 Absorbed dose in phantoms

Table IV shows the absorbed dose was obtained by irradiating to the phantoms. In the case of compressed phantom thickness of 3.2 cm, the absorbed dose resulting in the Monte Carlo method, the TLD and the Senographe 2000D was lower than recommended by the American College of Radiology. This dose is less than 3 mGy, because small breast thickness is not necessary to increase the dosage to achieve a clear image. While absorbed dose to the phantom thickness of 6.9 cm recorded the highest doses by DTLs. In these cases, surpass the limit of irradiation suggesting the Norma Oficial Mexicana, which is 3 mGy. For values of the thickness of 6.9 cm, the mammography equipment designate high values due to consistency of the phantom is higher than the breast tissue.

Tabla IV. Absorbed dose for breast phantom

Compressed phantom thickness [cm]	Monte Carlo [mGy]	Senographe [mGy]	DTLs [mGy]
Phantoms			
3.2	1.84 ± 0.06	2.21 ± 0.18	2.13 ± 0.23
6.9	3.46 ± 0.06	5.18 ± 0.43	4.19 ± 0.98

The difference in the results of 3 procedures is possibly due to the large number of variables that interact at the time of estimating the dose. Taken together, the values of the absorbed dose depending on the thickness of the breast are shown in Figure 6. In this figure one can notice that the majority of cases, and by any of the methods used to estimate the absorbed dose are below the limit defined in the Official Mexican Norm [10].

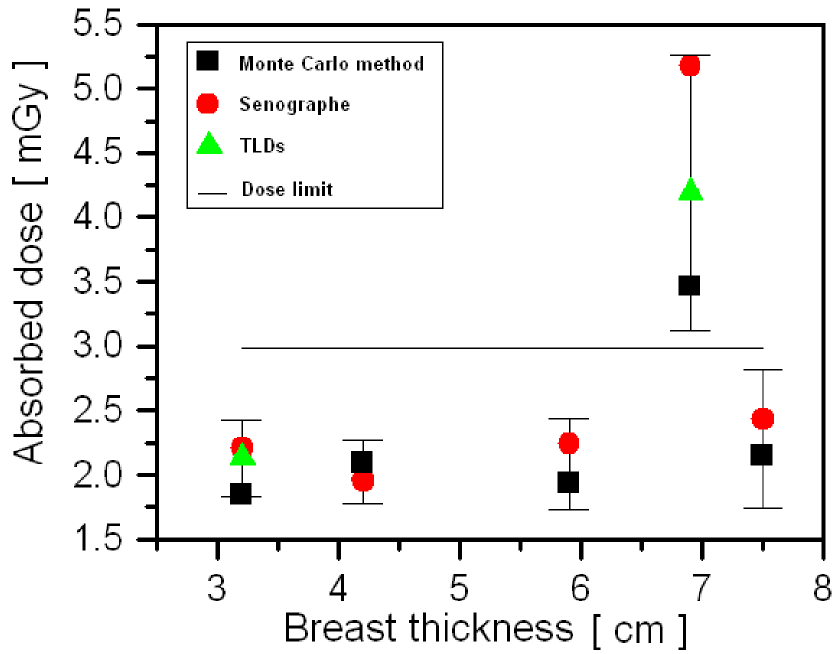

Figure 6. Values of the dose absorbed.

3. CONCLUSIONS

The mammography equipment is calibrated properly, because the values of the TLDs and Monte Carlo methods are close together, which means that no statistically significant differences. Requires the completion of a package that achieves estimate the dose in order to calibrate the equipment constantly and reduce the chances of radiation unnecessarily. The factors that mainly attributed to increasing dose of irradiation is the time and the applied current. In most cases analyzed, as well as measurements of the dose received by patients, is below the recommended limit of 3 mGy showing that there is a larger benefit, than risk, during mammography. Furthermore, the compressed breast thickness of the patient who could undergo a higher dose is 7.5 ± 1.01 cm. which is slightly on the maximum permissible dose (3 mGy). While for the compressed phantom thickness of 6.9 cm received the highest dose, exceeding the maximum allowable enough and the dose of other compressed breast thicknesses.

The three methods were used to obtain the dose, have a close approximation, so it can guarantee its effectiveness and allow the use of these in future research or in other hospitals. However, on exposure to the phantom thickness was greater becomes aware that the team selected exposure parameters leading to exceed 3 mGy, in which case could be obtained by varying the combination of mammography of anode / filter and potential or current operation. It is worth mentioning that patients undergoing mammographic studies in the General Hospital No. 1 IMSS Zacatecas area, most of its irradiation was used to filter an anode and Mo/Rh and Rh/Rh, which are not included in the Official Mexican [10]. With the above sets out the need to incorporate that standard criteria irradiation using filter anode and Mo/Rh and Rh/Rh. This is to establish limits of irradiation for features that are not covered in the Norma Oficial Mexicana.

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