Thermoluminescence Dosimetry in Quality Imaging in CR Mammography Systems

Enrique Gaona[*¥], Juan Azorín Nieto[¶,¥], J. Antonio Irán Díaz Góngora[¥], Manuel Arreola[§], J. Gabriel Franco Enríquez[*]

*Universidad Autónoma Metropolitana-Xochimilco, Calz. del Hueso 1100, 04960 México, D.F.
¶Universidad Autónoma Metropolitana-Iztapalapa, Av. San Rafael Atlixco 186, 09340 México, D.F.
¥CICATA Unidad Legaria Instituto Politécnico Nacional, Av. Legaria 694, 11599 México, D.F.
§Department of Radiology, Shands Hospital at UF, PO Box 100374, Gainesville, FL 32610-0374, USA

Abstract. The aim of this work is to estimate the average glandular dose with Thermoluminescence Dosimetry (TLD) and comparison with quality imaging in CR mammography. For measuring dose, FDA and ACR use a phantom, so that dose and image quality are assessed with the same test object. The mammography is a radiological image to visualize early biological manifestations of breast cancer. Digital systems have two types of image-capturing devices, Full Field Digital Mammography (FFDM) and CR mammography. In Mexico, there are several CR mammography systems in clinical use, but only one CR mammography system has been approved for use by the FDA. Mammography CR uses a photostimulable phosphor detector (PSP) system. Most CR plates are made of 85% BaFBr and 15% BaFI doped with europium (Eu) commonly called barium flourohalide. We carry out an exploratory survey of six CR mammography units from three different manufacturers and six dedicated x-ray mammography units with fully automatic exposure. The results show three CR mammography units (50%) have a dose that overcomes 3.0 mGy and it doesn't improve the image quality and dose to the breast will be excessive. The differences between doses averages from TLD system and dosimeter with ionization chamber are less than 10%. TLD system is a good option for average glandular dose measurement.

Keywords: Quality imaging, TLD, CR mammography.

INTRODUCTION

The aim of this work is to estimate the average glandular dose with Thermoluminescence Dosimetry (TLD) and comparison with quality imaging in CR mammography. The mammography is a radiological image to visualize early biological manifestations of breast cancer.

In Mexico, there are two types of image-capturing devices in mammography, film screen and digital. Currently the most commonly used device is film screen, primarily because of cost. Digital systems have two types of image-capturing devices, Full Field Digital Mammography (FFDM) and CR mammography.

In Mexico, there are several CR mammography systems printed to film in clinical use, but only one CR mammography system has been approved for use by the FDA

(Food and Drug Administration). Mexico has not regulations for accreditation of mammography facilities.

Mammography CR uses a photostimulable phosphor detector (PSP) system. Most CR plates are made of 85% BaFBr and 15% BaFI doped with europium (Eu) commonly called barium flourohalide [1]. The flexible CR plate is used in a cassette that is similar to screen-film cassette without a screen. CR plates are exposed in the same manner as screen-film. The latent image is stored on the CR plate in the form of trapped electrons. The CR plate is then read by the use of a stimulating red-wavelength laser that stimulates releases the trapped electrons resulting in a blue-green wavelength light emission. The output signal travels through a fiberoptic guide to a photomultiplier tube whose signal is converted to digital using an analog-digital converter. The stored signal contains the corresponding gray scale value along with a spatial position generated by the CR reader [2].

One of the great potential advantages of CR mammography arises from the decoupling of image acquisition and display. This allows flexible adjustment of image brightness and contrast and even permits enhancement of sharpness. It also presents a potential danger in that an image can be made to look reasonably good over a widely varying range of radiation exposure.

The problem in CR mammography is that if the dose is too high, the image quality will usually appear to be excellent, but the dose to the breast will be excessive and can be to increase breast cancer risk. Unless the relationship between the dose and the pixel signal value in the digitized image is known and monitored, this can easily occur without the operator being aware of it. Therefore, it is important to measure this relationship on the digital mammography unit.

The thermoluminescent dosimetry (TLD) was used for the estimation average glandular dose during quality control program of CR mammography units. For measuring dose, FDA and the ACR (American College of Radiology) use the phantom that was initially developed for the ACR, so that dose and image quality are assessed with the same test object. This phantom was designed to represent a 4.2 cm compressed breast composed of 50% glandular and 50% adipose tissues.

The conceptual model for this phantom was first introduced by Hammerstein et al. in 1979 [3]. Hammerstein et al. stated that the model was based on an educated estimate of the average breast in women [3]. The current ACR phantom that is used as the “average breast” in the United States is composed of a 4.2 cm thick acrylic block in which a wax insert is placed. The phantom was designed to mimic the automatic exposure response of a 4.2 cm compressed thickness with a 50% glandular composition. The wax insert contains objects to evaluate image quality [4,5].

MATERIAL AND METHODS

The exposure [4] of the x-ray system at the entrance surface to a breast specified compressed thickness is measured with a dosimeter. From the exposure, kVp and HVL (Half Value Layer), the average glandular dose is calculated using tables [4,6].

Four thermoluminescence detectors (TLD-100) are imaged with an ACR mammography phantom to correlate dose with image quality. The experimental

method employed for determining doses and calibration curve of TLD is illustrated in Figure 1.

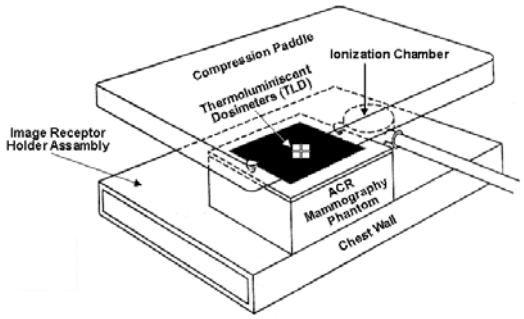

Figure 1. The exposure of the x-rays to TLD dosimeters and ionization chamber.

The exposure (X) is measured with ionization chamber and the average glandular dose is calculated using the equation 1 and tables [7].

$$D_g(mGy) = D_{gN}(Gm, HVL, kVp, tb) \cdot X \qquad (1)$$

Where D_g is average glandular dose, D_{gN} is the dose conversion factor using ACR Mammography Accreditation Phantom for 50% glandular/50% adipose tissue from the tables [4,6], HVL = 0.37 mm Al, kVp = 26 and X is the exposure at the entrance surface to ionization chamber (breast) [4,5].

The TLD reader system used was Harshaw 2000A-B, the mammography unit was GE-DMR+ with HVL = 0.37 mm Al, kVp = 26, Target/Filter combination Mo/Mo and *mAs* is varied for a series of exposures.

We carry out an exploratory survey of six CR mammography units from three different manufacturers and six dedicated x-ray mammography units with fully automatic exposure, HVL from 0.35 to 0.38 mm Al and a nominal large focal spot size of 0.3 mm were used for the image acquisition of phantom for quality control and dosimetry measurements and estimating average glandular doses

RESULTS AND DISCUSSION

The results of TLD calibration curve are illustrated in Figure 2 with 95% confidence intervals for mean.

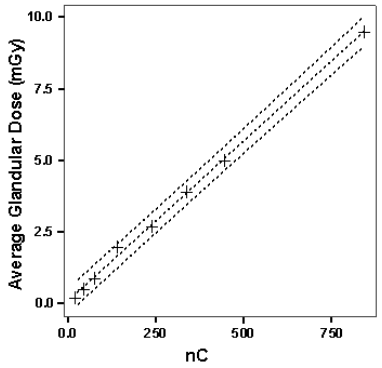

Figure 2. Calibration curve of TLD response and dose.

The curve can be defined as:

$$D_g(mGy) = -0.019717 + 0.0116545C - 4.57E - 07C^2 \quad (2)$$

Where D_g is average glandular dose, C is the charge collected in nC by termoluminescence dosimeters (TLDs).

The test quality image included scoring phantom images, mean optical density, density difference (contrast). The visibility of phantom details has been evaluated for CR mammography films with a viewbox for mammography with at least 3 000 nits [4,8]. The phantoms were imaged with fully automatic exposure in clinical conditions with range from 24 kVp and 26 kVp. The results of exploratory survey of the CR mammography units are illustrated in Table 1.

TABLE 1. Scoring phantom images.

Detector/system	Fibers visible	Specks visible	Mass visible	Mean optical density	Density difference
System scoring approved by FDA	4	3	3	At least 1.40	At least 0.40
System CR-1	3	3	3	1.86	0.51
System CR-2	4	2	4	1.20	0.40
System CR-3	4	2	3	1.30	0.26
System CR-4	4	3	4	1.61	0.45
System CR-5	5	4	4	1.74	0.61
System CR-6	4	3	4	1.45	0.52

The criteria for the number of objects to pass the ACR mammography accreditation are a minimum of the 4 largest fibers, the 3 largest speck groups, and the 3 largest masses. The optical density of the film at the center of an image of a standard FDA-accepted phantom shall be at least 1.40 when exposed under a typical clinical condition. The density difference between the background of the phantom and an added test object (4.0 mm acrylic) shall be at least 0.40 when exposed under a typical clinical condition [4,5,8].

The system resolution and average glandular doses comparison of the CR Mammography with Screen-Film Mammography are summarized in Table 2.

TABLE 2. Comparison of the system minimum resolution [5] and average glandular doses (D_g).

Detector	perpendicular to anode-cathode axis (11 lp/mm)	In the anode-cathode axis (13 lp/mm)	Average Glandular Doses (mGy) per view	
			(D_g) TLD System*	(D_g) Ionization Chamber**
System CR-1	4	8	3.52	3.71
System CR-2	4	8	1.82	1.74
System CR-3	4	4	1.49	1.38
System CR-4	4	4	3.27	3.05
System CR-5	8	9	2.50	2.61
System CR-6	4	8	3.83	4.05

*From equation 2, **from equation 1.

The average glandular dose delivered during a single cranio-caudal view of an FDA-accepted phantom simulating a standard breast shall not exceed 3.0 mGy per exposure in clinical conditions [5,8]. Quality image can be evaluate comparing the specifications of FDA and the results of each CR mammography unit

CONCLUSIONS

In Mexico, we have insufficient experience in image quality control and their effect in the average glandular dose in digital mammography. The results show three CR mammography units (50%) have a dose that overcomes 3.0 mGy and it doesn't improve the image quality and dose to the breast will be excessive. If quality image is not good, we won't be able to see early biological manifestations of breast cancer. The differences between doses averages from TLD system and dosimeter with ionization chamber are less than 10%. TLD system is a good option for average glandular dose measurement.

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