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Evaluation of the relation between breast glandular absorbed dose and radiographic quality in mammography

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Background: Breast is one of the main radiological sensitive organs, hence it is important to evaluate absorbed dose to this organ especially to the glandular parts. It is the aim of this study to measure mean glandular dose and image contrast in terms of different mammographic parameters. *Materials and Methods:* In this study two mammography machines located at Said-al Shohada (Giotto) and Shahid Behesti (GE) hospitals were used. According to the recommendations of ACR and MQSA, breast phantoms were constructed and used for this study. For dose evaluation TLD dosimetry method was used. The TLD dosimeters were of LiF type and the reader was a Solaro TLD reader. *Results:* To obtain a constant contrast when increasing kVp from 22 to 24, it was necessary to reduce mAs by 12 percent. The obtained relation between these two parameters is: contrast=0.2829D-0.2427. It was also found that there is a linear relationship between contrast and image quality. The relation between these two parameters is: Image quality = 28.117 Contarst + 20.134. Increasing kVp and hence decreasing mAs results a reduction to the glandular dose, especially in patients with large breast. Increasing kVp from 28 to 30 results in reduction of dose from 6.8mGy to 5mGy. Conclusions: It was found that there has been a linear relationship between contrast and image quality. It was also found that increasing kVp necessitate to reduce mAs for a constant contrast and hence reduction of glandular dose. **Iran. J. Radiat. Res., 2008; 6 (2): 77-82**

Keywords: *Mean glandular dose, radiographic contrast, radiographic quality, mammography, TLD dosimetry.*

INTRODUCTION

Precise radiography of breast tissue drew considerable attention since the time it was figured out that about one woman out of eight would suffer from breast cancer during life [1]. The breast cancer diagnosis in its early stage boosts great chances for determining a successful treatment plan for the patients [2].

Mammography plays a central role in screening plans. On the other hand, breast is one of the most sensitive organs to ionizing radiation [3-5]. The cancer risk by mammography absorbed X-ray always must be taken into account.

In widespread examinations of screening in which the healthy population is included, ionizing radiation application must be done with great care. In mammography it is to acquire high quality images to detect cancer in the early stage by using acceptable radiation dose which minimizes the risk of cancer. Radiographic quality, mAs, mean glandular dose and radiographic contrast are the main quantities which must be taken into consideration in each examination. One of the crucial factors affecting the image quality and radiation dose is the radiation quality. Radiation quality itself depends on the material of anode-cathode, the filter and kVp [6, 7]. Radiation dose and radiation quality also depend on the breast size. As recommended by Mammography Quality Standards Act (MQSA), since 1992, each mammography apparatus must be under some integrated tests in order to examine the mean glandular dose and the radiographic quality.

To achieve this goal, American College of Radiology (ACR) presented a series of standard evaluation plans [9]. The effect of the changes in radiation quality on the

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image quality appears in contrast changes. Increasing the contrast leads to the increase of image quality. To examine the mentioned quantities a proper phantom should be used. The phantom should be equivalent to a standard breast, composed of 50% fat and 50% gland with 5mm fat surface layer.

Image quality is determined based on the number of visible objects on the object plane of the phantom. In this study the effect of radiation quality changes (kVp) were investigated on mAs, radiation dose, contrast and quality of the image and the effects of breast thickness changes on the contrast and mean glandular dose.

MATERIALS AND METHODS

For this research two mammography machines located in Seyed-al-Shohada and Shahid Beheshti hospitals in Isfahan were used. The system in Seyed-al-Shohada carried the commercial name of Giotto (model MXS-50m0H made in Italy). The filter of the device was 0.5mm of Beryllium (Be), the target material was made of Molybdenum (Mo), and the added filter was 0.03mm of Molybdenum (Mo). Mammographic system in Shahid-Beheshti hospital was made by general electric (GE) company, having a filter of 0.8mm Beryllium (Be) and the target material of Molybdenum and Aluminum. For GE mammography device, Fuji film and for Giotto device Kodak film was used. The developing solution in both cases was Champton. The developing stages take place automatically in the dark room.

Phantom was constructed as recommended by ACR and MQSA and imitated TOR (MAM) and TOR (MAX) [10]. The object was made up of a material by which similarity to the standard breast tissue was observed regarding the radiation absorption and scattering as it was explained earlier. In this research for breast phantom polymethylmethacrylate (PMMA) was used as it was used by other investigators [10, 11]. Figure 1(a) shows a sketch of this phantom. The phantom had an object plane on which three groups of fibrous, nodules and calcifications in different sizes were simulated. The plane was used in order to evaluate the image quality. Also it included step model from Al sheets to study contrast and bar model from nylon to study the resolution [11]. The following three substances were used to simulate the breast components: Calsit (calcium carbonate) for micro calcifications [12], a sort of plastic called Mylar with the density of d = 1.39 gr/cm^3 for nodules [13] and nylon threads for fibrous structure.

These threads had lengths of 10mm and with different thicknesses situated in three direction of parallel, vertical and having the angle of 45° to anode-cathode. Each step model was made from one to eight aluminum layers, 10mm long and 0.06mm thick. Bar models were placed in horizontal and vertical along the direction of cathode – anode in order to examine the resolution of the device. The model contained various groups. Each group was consisted of bars whose numbers in length unit on millimeter scale had been different. The numbers of pair bars were extended from eight to twenty per milimeters. The importance was the width of the bars and the distances between them which varied from 1/16mm to 1/40mm. The width of bars in each series was equal to the width of space between them. The bars were made up of copper with high absorption coefficient, and the space between them was made up of a material with low absorption. Figure 1(b) demonstrates a sketch of object plane of the phantom. In table 1 the characteristics of the different elements are shown. By adding and subtracting D-shaped planes having 10mm thickness made of PMMA, a phantom with different thicknesses of breast was obtained.

Dosimetry

To measure absorbed dose, Thermoluminescent detectors (TLD) were used. TLDs used in this experiment were disc-shaped having diameter of 6mm and the thickness of 1mm, made up of LiF (from NE Technology limited in UK). LiF's behavior was highly similar to the tissue when subjected to radiation, therefore it was proper for dosimetry. For doseimetry, TLD detectors were placed in a Perspex plane. During measurement, the object plane was extracted, and a plane containing the detectors was replaced instead at the end of the thickness of the phantom.

Five TLD detectors are fixed on the dosime-try plane all of which were used to measure the mean glandular dose. To read the TLD, an automatic double-channel TLD reader of Solaro 2A made by NEC Company was used.

Image quality and contrast

To study the contrast, the thickest of

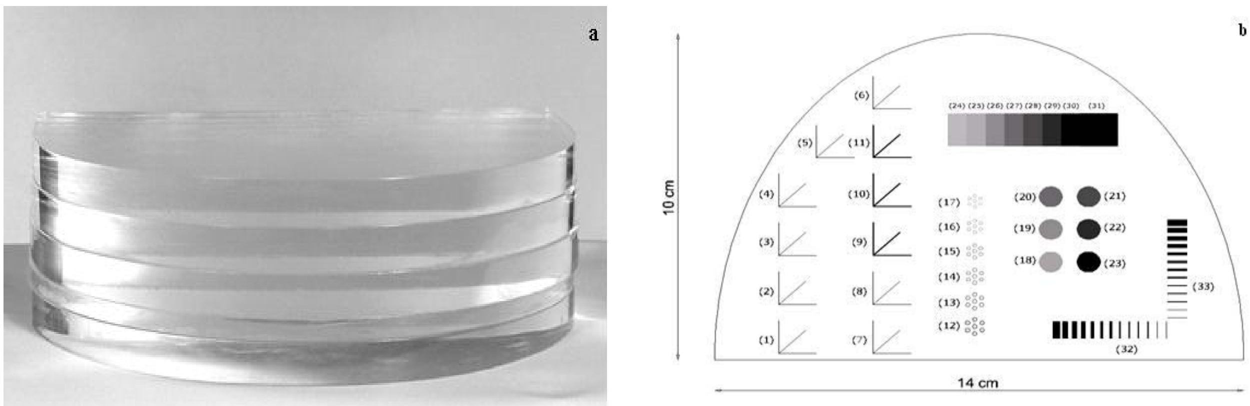

Figure 1. a) A photography of a constructed phantom. It is consisted from five 10mm thick pieces of D shaped Perspex each with 14cm diameter. b) Phantom structure and components. It is a 0.7cm thickness of parathion containing several components for contrast and spatial resolution in different directions.

Table 1. Different components used in construction of phantom and their sizes.

Nylon Threads (fibrous) 1mm long											
Group No.	1	2	3	4	5	6	7	8	9	10	11
Thickness (mm)	0.18	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.1	1.2	1.3
Calcium Carbonate as the microcalcification											
Group No.	12	13	14	15	16	17					
Thickness (mm)	0.125	0.20	0.25	0.50	0.80	1.00					
Miler discs as the nodules											
Group No.	18	19	20	21	22	23					
Thickness (mm)	0.125	0.20	0.25	0.50	0.70	1.00					
Aluminum step model											
Group No.	24	25	26	27	28	29	30	31			
Thickness (mm)	0.06	0.12	0.18	0.24	0.30	0.36	0.42	0.48			
Copper Bar Model											
Group No.	32	33									
lp/mm	8-20	8-20									

the step model being 0.48mm thick of aluminum was used as the base. Contrast was obtained from the optical density difference between aluminum thickness and the substrate.

Optical density was measured from the radiographic film with densitometer model RMI 2-331 made by X-Rite Incorporation (USA) having the accuracy of up to 0.02D.

Radiation quality

Radiation quality can be changed by making the changes in the voltage kV_p whose effect on the mean glandular dose in the glands, quality and contrast of image was examined.

RESULTS

Tube kV_p was increased from 24 kV_p to 28kV_p. For each selected kV_p, the amount of mAs and the mean glandular dose was measured to obtain a constant contrast. The variation of mAs with the increasing of kV_p is represented in figure 2.

As seen, increasing kV_p resulted in mAs decrease. The variation of the mean glandular dose (MGD) with the kV_p variation for 42mm thick phantom with constant contrast is shown in figure 3. The amount of dose decreases by 12% as the voltage increased from 24 kVp to 28kV_p.

Contrast variation with the mean glandular dose for a phantom being 52mm thick having correlation coefficient of 0.94 is shown in figure 4. Also, in figure 5 the image contrast variation (with identifiable details) with contrast variation for a phantom being 42 mm thick with the correlation coefficient of 0.98 is shown. As it is noticed, there is a liner relation between contrast and image quality. Dose variation with the variation of thickness of the phantom in a constant contrast of 0.5 is shown in figure 6. Dose amount increases with the rising thickness of the phantom, and three thicknesses of 32, 42 and 52 mm of the phantom have been used.

Dose amount was increased from 1.4 mGy to 4.5 mGy. Figure 7 shows contrast variation for these three thicknesses under the constant dose for 26 kV_p radiation.

At 26 kVp and constant contrast with

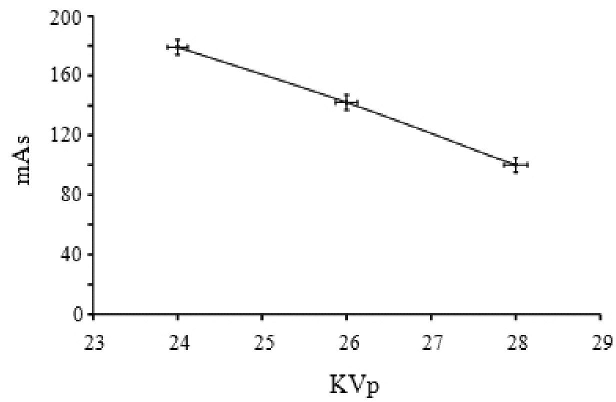

Figure 2. The mAs variation with the variation of tube kV_p in a constant contrast (the measurements were repeated three times).

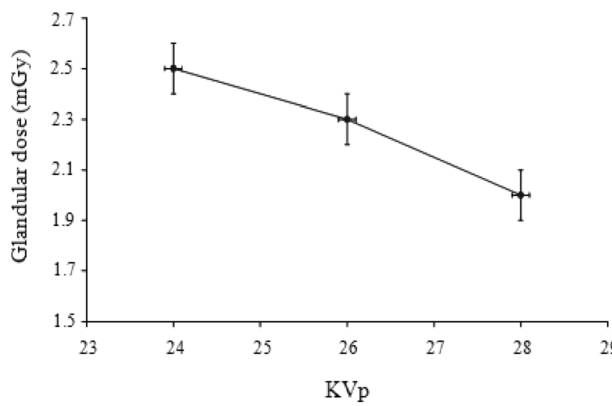

Figure 3. Glandular dose variation with kVp radiation quality for the 42mm thick phantom in a constant contrast. The results are the mean from three measurements.

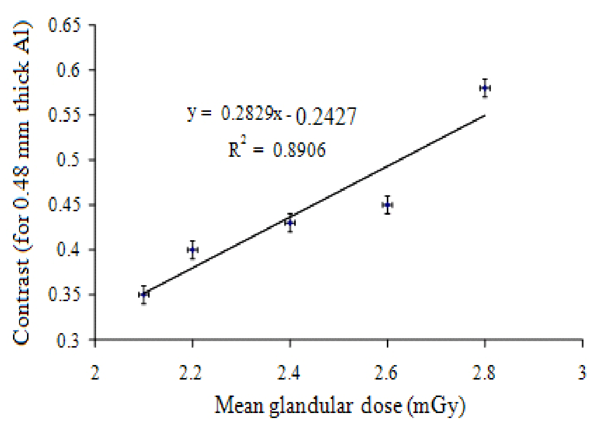

Figure 4. Contrast variation with the variation of mean glandular dose (mGy) for 52 mm thick of phantom (the measurements were repeated three times).

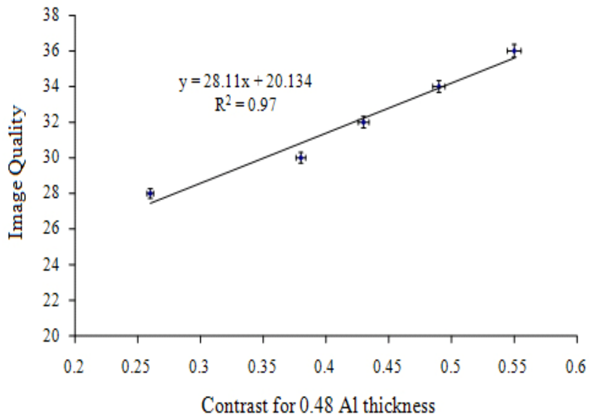

Figure 5.Variation of image quality with the variation of contrast for the phantom being 42 mm thick (the measurements were repeated three times).

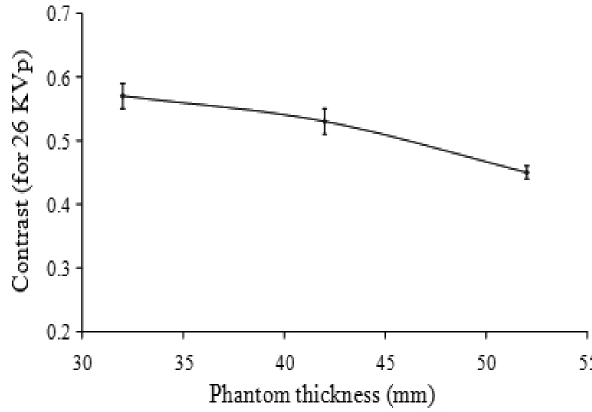

Figure 7. Contrast comparison for three phantoms of different thicknesses for radiation quality of 26KVp in constant dose (the measurements were repeated three times).

the rising of thickness, a falling in contrast can be observed from 0.57 to 0.42 for 0.48 mm thick aluminum.

DISCUSSION

The obtained results in this research show that kV_p rising results in mAs falling while the contrast was constant. An increase in kV_p led to the decrease of radiation time and consequently mAs amount decreases (figure 2).

According to the observations, applying the higher quality radiation in lower mAs has resulted in the falling of patient dose. In figure 5 the relation between the dose amount and contrast for a 52mm phantom

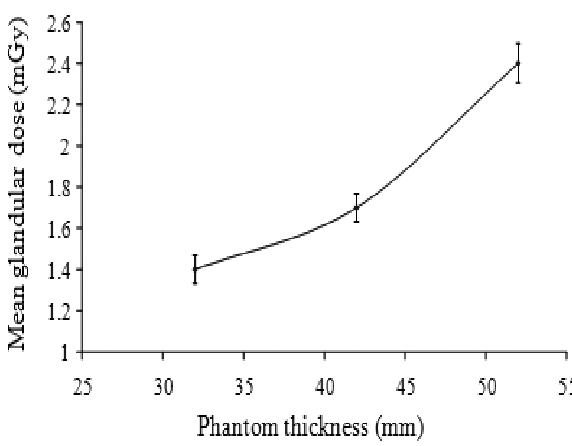

Figure 6. Comparison of mean glandular dose between three phantoms with different thicknesses in constant contrast of 0.5 (the measurements were repeated three times).

are demonstrated. In thicker breasts as the contrast rises, the dose amount falls.

By utilizing higher kVp_s for thicker breasts the mean dose can be reduced, while the reduced contrast is negligible. There has been a good consistency between this result and the theoretical results. The contrast decreased as a result of hardening the radiation or the increase of scattering which happened as a result of the increase of breast thickness or density.

There was a linear relation between contrast and quality of image with a correlation coefficient of 0.98. As the contrast increased the quality of image (which is the amount of clarity of the elements on the object plane of the phantom) in mammogram increased as well.

In 1996 Yang and his colleagues came to the similar conclusion in their experiments. By increasing the kVp in one target material and fixed filter Mo/ Mo they observed that the amount of dose declined. Besides, by simulating the standard breast being 70mm thick with Perspex planes they noticed that as the voltage of X-ray generating tube increased from 28 kVp to 30 kVp, the dose and contrast decreased from 6.8mGy to 5mGy, and from 0.24 to 0.22, respectively.

In 2002 Lavoy and his colleagues in

other researches examined the effect of kV_p on quantities such as mAs, MGD, radiation time and HVL with the final goal of radiation quality effect study. According to their results, to gain constant contrast by increasing kV_p, the amount of mAs and also dose would decline. For instance, increasing the voltage from 25 kV_p to 26 kV_p caused 25% decline in radiation time and ultimately mAs and 10% dose decreased appear, as well.

On the whole, having increased the kV_p in one compound target material and fixed filter resulted in the improvement of the radiation; therefore, the patient dose was cut down.

By increasing kV_p and decreasing the mAs the patient dose would reduce while the contrast either would remain constant or manifest a negligible decrease. With having a proper adjustment of kV_p voltage and mAs especially for the thick breasts, it will be possible we will be able to improve both the absorbed dose and image quality of mammograms.

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