8

Assessment of AGD in UAE Hospital

Najlaa Almazrouei
Dubai Health Authority (DHA)–Medical Physics Section
United Arab Emirates

1. Introduction

X-ray mammography is the most reliable method of detecting breast cancer. It is the method of choice for the Breast Screening Program in a variety of developed countries In order to obtain high quality mammograms at an acceptable breast dose, it is essential to use the correct equipment.

In the United Arab Emirates (UAE), the number of mammography examinations has been rising steadily the past few years due to the rapid economic growth of the country and the increasing use of computed and digital radiography systems, as film based mammography systems are being abandoned progressively.

At present, there is a growing concern about the radiation doses incurred by patients when undergoing breast examinations. For this reason, the UAE has decided to join the IAEA Task4 project to undertake a survey of patient exposure in digital mammography in several Hospitals.

The objectives of this work are

- Achieve consistently high quality mammograms.
- Limit radiation dose by determine the Average Glandular Dose (DG) resulting cranio-caudal - projections.
- IAEA guidance was used for measuring the Entrance Surface Air Kerma (Ka,e) and EUREF - guidelines DG calculations.
- Minimize the number of supplementary and repeat examinations.
- Minimize the number of unnecessary invasive procedures.
- The main objective of this work was to evaluate the Average Glandular Dose (DG) resulting from exposure to mammographic X-rays while the ultimate aim of the project remains the establishment of Dose Reference Levels (DRL) in the UAE.

It is worth noting that the quantities and symbols used in this presentation are those suggested by the International Commission on radiation Units and Measurements (ICRU) in its publication 74.

The Total numbers of mammography system in Dubai are 26 facilities both in Governmental and Privet sector, the Average number of patients per year were 528, the number of CR system 18, the DR system 5 and the screen film 3.

There are some factors affecting the visibility of the objects:

Size, Contrast & Noise (from different sources)

Also the following Exposure parameters:

Anode (Mo, Rh, W...) => contrast, (resolution)

Filter (Mo, Rh, Al...) => contrast

Tube voltage (kV) => contrast

Dose or tube loading (mAs) => noise

Radiation dose to the breast is affected by the following parameter

- The breast composition and thickness
- The photon energy
- The sensitivity of the image receptor
- The breast composition has a significant influence on the dose
- The area of the compressed breast has a small influence on the dose
- Majority of the interactions are photoelectric

A Quality Control program should ensure:

- The best image quality
- With the minimum dose to the breast
- Hence regular check of important parameters

2. Methodology, equipment and tools used to perform the study

For tube quality

- Victoreen NERO mAx 8000 multimeter + Fluke Biomedical Detector
- Gamex test tool
- Unfors kit (as a substitute when Victoreen was not available)

For checking image quality

- ToRMAX-316 (Leeds Test Object) for Detailed Image (total thickness 7 cm)
- ACR phantom for general image

For measuring the Contrast-to-Noise-Ratio (CNR)

- ToRMAX-316 (Leeds Test Object)
- 2 cm x 2 cm piece of aluminum of thickness 0.2 mm
- ACR phantom

For the measurement of ESAK

- Victoreen NeroMax 8000 multimeter + Victoreen cylindrical Ion chamber 3.3 cc or
- Unfors kit (as a substitute when Victoreen was not available)

2.1 Quality control of the mammography machines

All parameters relevant to X-ray beam (mainly kVp, HVL & light field collimation) should be checked.

2.1.1 KVp accuracy

Method:

- Turn on the Victoreen NERO Max 8000 and select the Mammography option then press enter.
- Place the Victoreen NERO mAx 8000 Detector on the table.
- Insert 22-35 filters to the detector.
- Give exposure and write down the effective KVp and Dose.
- Action Limit: If the measured kVp differs more than ±5% of the set kVp then seeks service correction

2.1.2 Reproducibility

Method:

- Turn on the Victoreen NERO Max 8000 and select the Mammography option then press enter.
- Place the Victoreen NERO mAx 8000 Detector on the table.
- Insert 22-35 filters to the detector.
- Give exposure and fill down the table.
- Action Limit: if the coefficient of variation exceeds 0.02, then seek service correction.
- Formula used for calculation:

$$SD = \sqrt{[n \sum x^2 - (\sum x)^2 / n (n - 1)]} \quad (1)$$

$$CV = SD / Mean \quad (2)$$

2.1.3 Beam quality test (HVL)

Method:

1. Raise the compression paddle to its highest position. Mount the 6000-529 ionization chamber on a ring stand so there is approximately 5 cm of space between the bottom of the chamber and table. The chamber should be centered in the beam laterally, and approximately 4 cm from the chest wall.
2. Collimate the beam, using the light field, so that the entire chamber is included in the beam. The field should be approximately 6 cm x 6 cm. If necessary, relocate the chamber such that it is centered in the field.
3. Set the kVp selector at a kVp setting that is frequently used for making mammograms.
4. Connect the chamber to the Nero Max8000 device.
5. Make an exposure. Note the reading and label it X0.
6. Place a sheet of aluminum 0.2 mm thick on the compression paddle. Using the collimator light, be sure the entire ionization chamber is in the shadow of the aluminum sheet. Make an exposure. Record the reading and label it X1; also record the thickness of aluminum used to make the exposure. Label it t1.
7. Place an additional 0.01 mm of aluminum on top of the aluminum absorbers) already in place. Make an exposure. Record the reading, labeling it with sequential indices. Also, record the total thickness of aluminum used in making the measurement, labeling it as

tN where N is the total number of filtered exposures taken so far. If XN is less than one half of X0 proceed to step 7, otherwise, repeat step

8. It is now assumed that you have compiled a list of data pairs, labeled "ti" and "Xi"- If N is the total number of filtered exposures, then the half-value layer may then be calculated using the following formula:

$$HVL = \frac{{}^{t}N^{1n}\left\{2XN-1/x_0\right\} \ -{}^{t}N - \ 1^{1n}\left\{2XN/x_0\right\}}{1n\ \left\{XN-1/XN\right\}} \tag{3}$$

2.2 Image quality

For general image, we use the ACR mammography phantom contains test objects that are similar to microcalcifications, fibers, and masses

- Image quality tests were performed at clinical settings to ensure that the X-ray machines were functioning properly, in accordance to the manufacturer’s specifications.
- Place the phantom on the image receptor surface in the same position as a breast. The nipple indent marker should be positioned away from the chest wall, just as the nipple of the patient’s breast would be positioned.
- Position the x-ray tube and compression device as you would for a craniocaudal examination of a patient’s breast.
- Choose the kVp and mAs factors as you would use for an average 4.5 cm breast and make an exposure.
- The image will represent the imaging abilities of your machine using these clinical factors.
- If the image is over or under exposed, make a suitable adjustment in your factors and repeat the exposure.
- This is an indication that adjustments may be necessary for patient imaging of these compressed breast thicknesses and should be checked.

Use the ToRMAX-316 (Leeds Test Object) for Detailed Image (total thickness 7 cm) and repeat the pervious step for each breast thickness.

Image 1. ToRMAX-316 (Leeds Test Object).

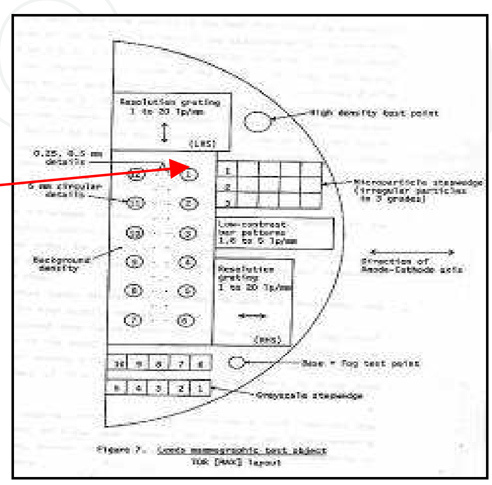


Image.2

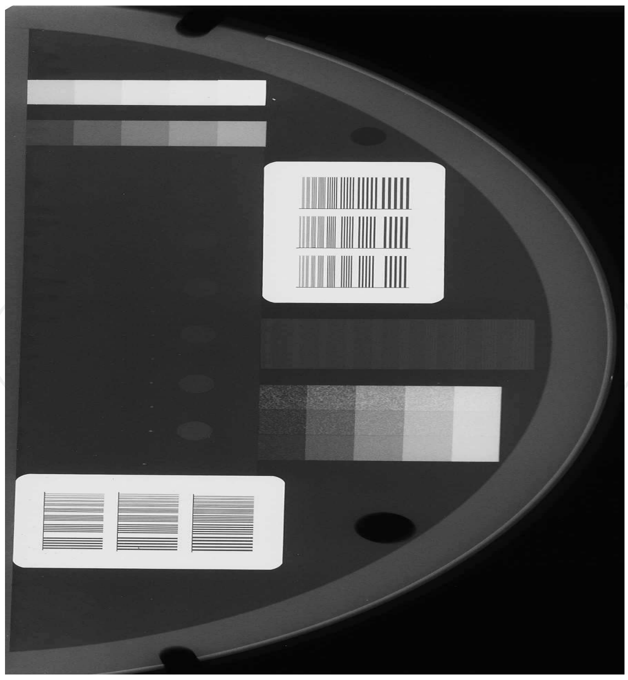


Image 3. this image reflect the image that we got from the phantom after exposure.

2.3 Contrast-to-Noise Ratio (CNR)

- The Contrast-to-Noise Ratio (CNR) was determined by placing a square-shaped 2 cm x 2 cm piece of aluminum of thickness 0.2 mm on the PMMA phantom, 6 cm from the edge of the phantom and table, in the centre of the phantom.
- Two ROIs of 4 cm2 were selected in the saved image to calculate the mean (S) and the standard deviation (σ).

The Contrast-to-Noise Ratio (CNR) is obtained using the equation:

$$CNR = \frac{S_{AL} - S}{\sqrt{\sigma_{AL}^{2} + \sigma^{2}}} \tag{4}$$

2.4 Average Glandular Dose, DG

The AGD cannot be measured directly but it is derived from measurements with the standard phantom for the actual technique set-up of the mammographic equipment.

The measurements of the Entrance Surface Air Kerma Ka,e were performed in two steps,

First

1. Set up the x-ray machine for a typical mammographic technique. Place a loaded cassette in the cassette holder, of the size and type consistent with the examination being simulated. Set the machine in the AEC mode and set the density control to the position most commonly used for the examination.
2. Place a mammographic LTO phantom on the cassette holder assembly at the position normally occupied by the breast. Be sure the phantom completely covers the AEC sensor.

3. The LTO phantom was exposed to X-ray beams using automatic mode to get the kVp, mAs, and target/filter combination used.
4. Then, remove the phantom and a similar exposure will perform in manual mode with no phantom.

Second

1. Now, place the Model 6000-529 ionization chamber in the center of the phantom.
2. Lower the compression paddle until it contacts the chamber. Take care not to put any mechanical stress on the chamber.
3. Connect the chamber cable to an NERO max8000; Follow the instructions accompanying the instrument for details of instrument operation.
4. Make an exposure. Record the reading from the electrometer. Apply whatever corrections are necessary to yield an accurate exposure reading.
5. Repeat step 4 three more times. Average all four results. The final result is the breast entrance exposure. You should now repeat the procedure for all other clinically used techniques. The value of Ka, e, the Entrance Surface Air Kerma (ESAK) is deduced

$$K_{a,e} = O_d \, P_{It} \, (d_{sd} / (d_{sd} - T))^2 \quad (5)$$

Od = Tube output at level of detector
Pit= Tube current exposure time product (mAs)
dsd= Source to detector distance
T= Thickness of compressed breast (CBT)

Conversion factors from incident air kerma to average glandular dose have been obtained using Monte Carlo transport calculations in simple breast models e.g. Dance et al (2000)

The Average Glandular Dose DG is calculated as:

$$DG = K_{a,e} \, . \, g. \, c. \, s \quad (6)$$

- Where ***Ka,e*** is the entrance surface air kerma (without backscatter) calculated at the upper surface of the PMMA.
- The factor g, corresponds to a glandularity of 50%, and is derived from the values calculated by Dance et al 2000 and is shown in table.1 for a range of HVL.
- The c-factor corrects for the difference in composition of typical breasts from 50% glandularity [Dance et al 2000] and is given here for typical breasts in the age range 50 to 64 in table.2.
- Typical values of HVL for various spectra are given in table.3. The factor **s** shown in table 4 corrects for differences due to the choice of X-ray spectrum (Dance et al 2000).

Note that the c and g-factors applied are those for the corresponding thickness of typical breast rather than the thickness of PMMA block used. Where necessary interpolation may be made for different values of HVL.

The dose should be determined using the usual clinically selected exposure factors including any automatic selection of kV and target/filter combination.

PMMA Breast Thickness (mm)	Equivalent Breast Thickness (mm)	g-factors (mGy/mGy) HVL (mmAl)							
		0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
20	21	0.329	0.378	0.421	0.460	0.496	0.529	0.559	0.585
30	32	0.222	0.261	0.294	0.326	0.357	0.388	0.419	0.448
40	45	0.155	0.183	0.208	0.232	0.258	0.285	0.311	0.339
45	53	0.130	0.155	0.177	0.198	0.220	0.245	0.272	0.295
50	60	0.112	0.135	0.154	0.172	0.192	0.214	0.236	0.261
60	75	0.088	0.106	0.121	0.136	0.152	0.166	0.189	0.210
70	90		0.086	0.098	0.111	0.123	0.136	0.154	0.172
80	103		0.074	0.085	0.096	0.106	0.117	0.133	0.149

Table.1. g-factors for breast simulated with PMMA.

PMMA Breast Thickness (mm)	Equivelant Breast Thickness (mm)	Glandularity of Equivelant Breast	c-factors (mGy/mGy) HVL (mmAl)						
			0.30	0.35	0.40	0.45	0.50	0.55	0.60
20	21	97	0.889	0.895	0.903	0.908	0.912	0.917	0.921
30	32	67	0.940	0.943	0.945	0.946	0.949	0.952	0.953
40	45	41	1.043	1.041	1.040	1.039	1.037	1.035	1.034
45	53	29	1.109	1.105	1.102	1.099	1.096	1.091	1.088
50	60	20	1.164	1.160	1.151	1.150	1.144	1.139	1.134
60	75	9	1.254	1.245	1.235	1.231	1.225	1.217	1.207
70	90	4	1.299	1.292	1.282	1.275	1.270	1.260	1.249
80	103	3	1.307	1.299	1.292	1.287	1.283	1.273	1.262

Table 2. c-factors for breast simulated with PMMA.

HVL (mm Al) for target filter combination					
Kv	Mo + 30 µm Mo	Mo +25 µm Rh	Rh +25 µm Rh	W +50 µm Rh	W +0.45 µm Al[22]
25	0.33 ± .02	0.40 ± .02	0.38 ± .02	0.52 ± .03	0.31 ± .03
28	0.36 ± .02	0.42 ± .02	0.43 ± .02	0.54 ± .03	0.37 ± .03
31	0.39 ± .02	0.44 ± .02	0.48 ± .02	0.56 ± .03	0.42 ± .03
34		0.47 ± .02		0.59 ± .03	0.47 ± .03
37		0.50 ± .02			0.51 ± .03
* Some compression paddles are made of Lexan, the HVL values with this type of compression plate are 0.01 mm Al lower compared with the values in the table.					

Table 3. Typical HVL measurements for different tube voltage and target filter combinations. (Data includes the effect on measured HVL of attenuation by a PMMA compression plate*.)

Spectrum	s-factor
Mo/Mo	1.000
Mo/Rh	1.017
Rh/Rh	1.061
Rh/Al	1.044
W/Rh	1.042
W/Al	1.05*

*This value is not given in the paper of Dance et al. The value in the table has been estimated using the S-values of other spectra.

Table 4. s-factors for clinically used spectra [Dance et al. 2000].

The recommended achievable and limiting dose values in the European guidelines for the same PMMA thickness (van Engen et al 2006) are 0.6, 1, 1.6, 2, 2.4, 3.6, 5.1 mGy and 1, 1.5, 2, 2.5, 3, 4.5, 6.5 mGy respectively for 2, 3, 4, 4.5, 5, 6 and 7 cm of PMMA.

In our survey we use the limiting dose values to compare our date with it, as it will be shown in the next figures.

PMMA thickness (cm)	European Guild lines for the Limits AGD (mGy)
2	1
3	1.5
4	2
4.5	2.5
5	3
6	4.5
7	6.5

Table.5. European guild line for limit AGD (mGy) for at different PMMA thickness (cm).

3. Discussion

The Results of the measured Average Glandular Dose (AGD) were performed on different breast thickness, we chose 2cm breast thickens, 4.5 cm breast thickens which simulate the standard breast thickens and the third thickens was 7 cm, so in our survey we were covered the small, medium and large breast thickness.

We inspected (21 facilities), and 4 of them have a DR mammography, 13 CR mammography and 3 screen film mammography.

Results of the DR Mammography system

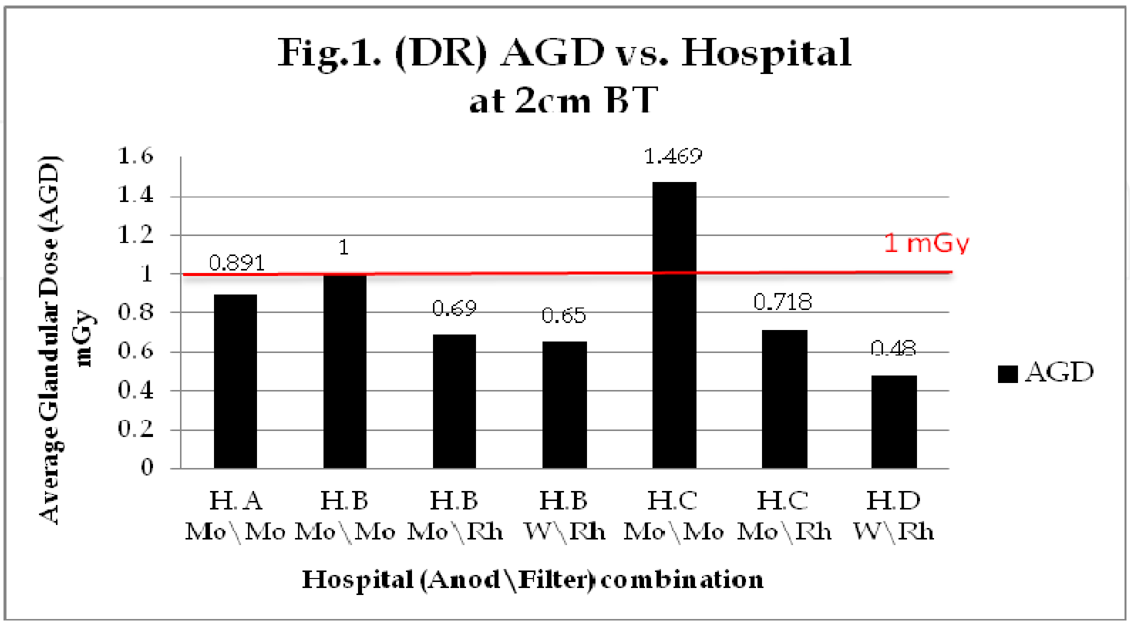


Fig. 1. ((DR) AGD vs. Hospital at 2cm BT), shows that one hospital (H.C Mo\Mo) is exceeding the acceptable limits, it was a test to observe the differences between the different Anode\Filter combinations that their machine have, and they are using the automatic mode (Auto-Kv mode) to acquire their images.

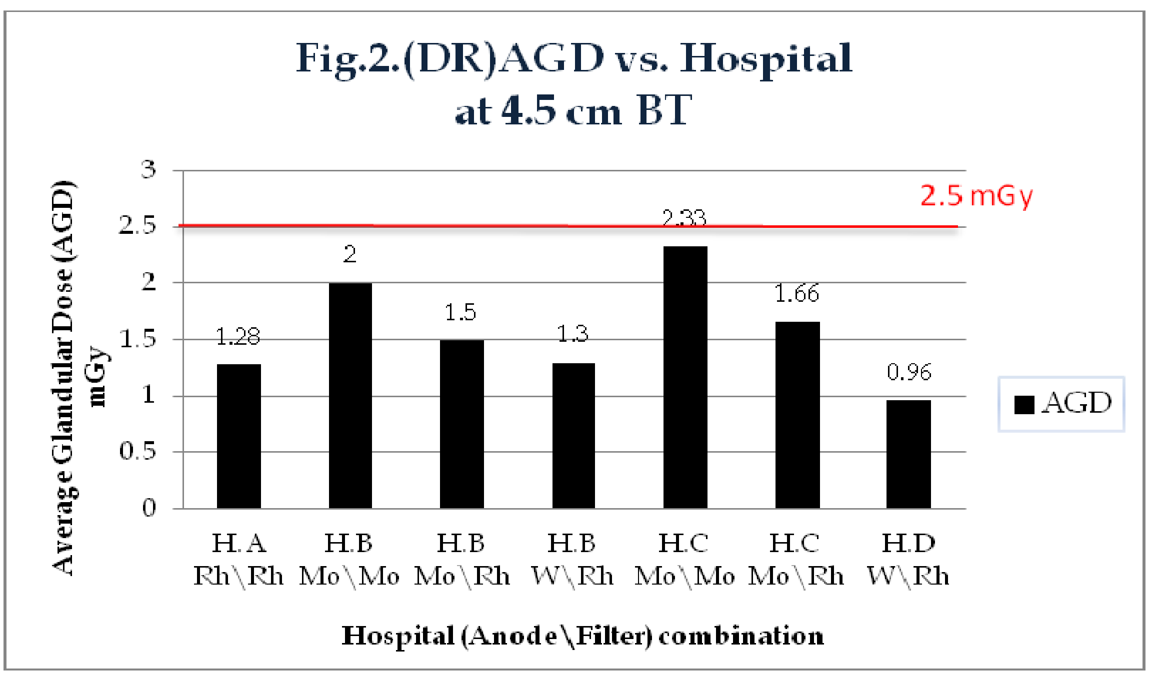


Fig. 2. ((DR) AGD vs. Hospital at 4.5cm BT), we observe that all hospital were within the AGD acceptable limit, all theses hospital are using the automatic mode to acquire their images, Except hospital A & B, the technician control the Kv parameter depending on the breast thickness.

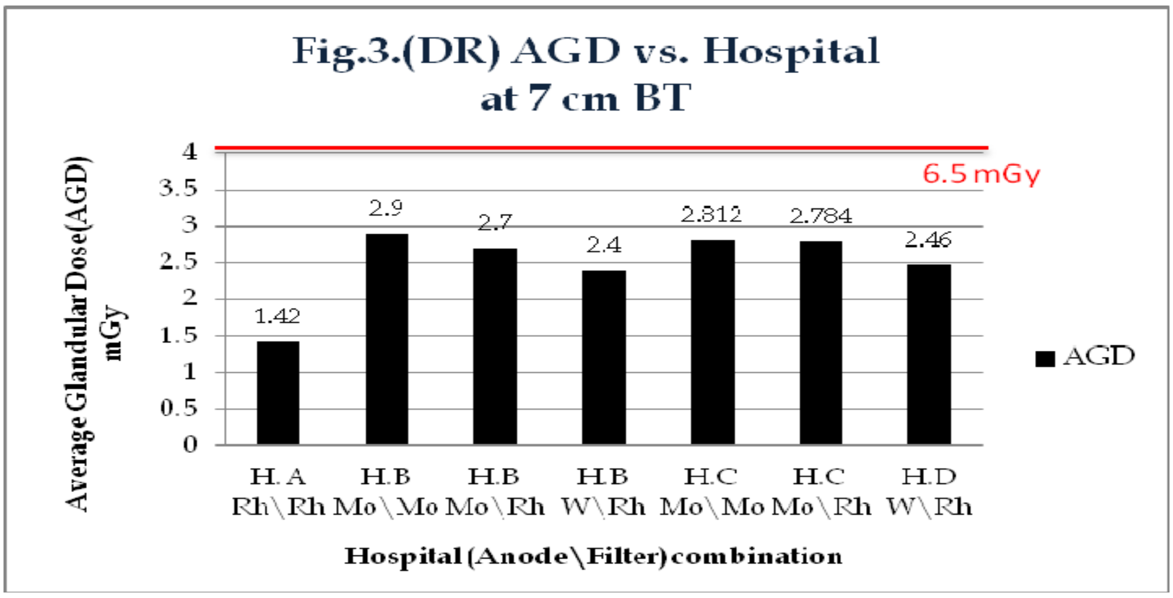


Fig. 3. ((DR) AGD vs. Hospital at 7cm BT), shows that all hospitals are below the AGD acceptable limit, all theses hospital are using the automatic setting to acquire their images, Except hospital A & B, the technician use the manual setting for the Kv parameter depending on the breast thickness.

Result of 13 Computed Mammography machine

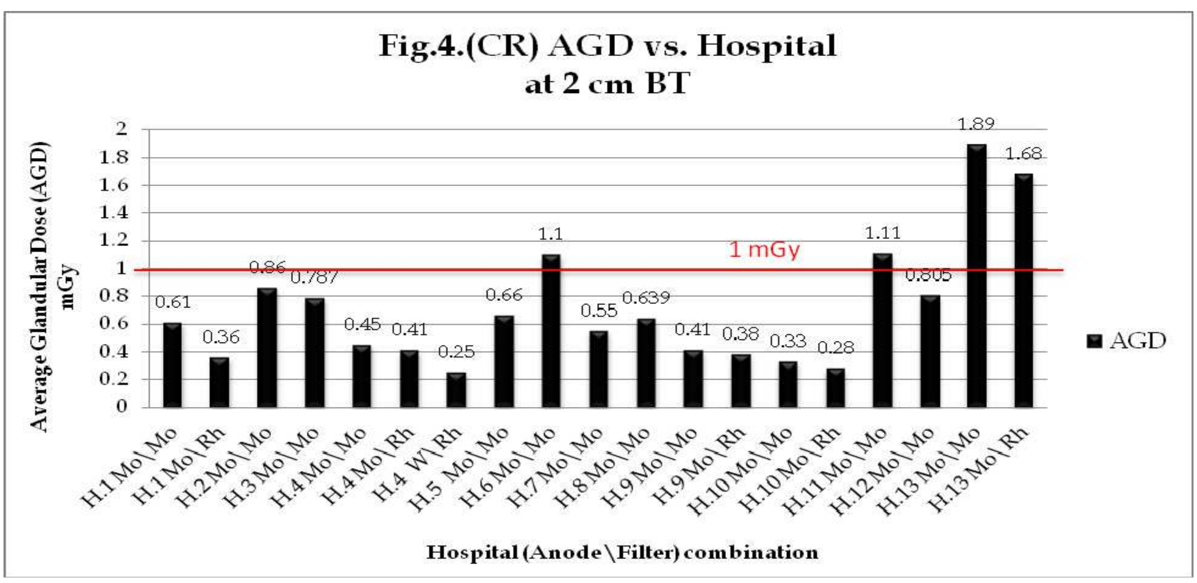


Fig. 4. ((CR) AGD vs. Hospital at 2cm BT), we observe from this figure that there are 3 hospitals were exceeding the AGD acceptable limit, which they are H6, H11&H13 with different anode\filter combination. H6: they are using the automatic mode, H11: they only have one Anode\Filter combination they use manual setting for Kv and automatic setting for mAs they were advice to change their setting to reduce the dose. H13: the technician were use the manual mode for acquiring their images , they were advised to fix call the service to fix their machine on the same time their cassette also were old and it was need to be changed. Regarding the other hospitals the most of them were fully automatic and the other have manual Kv settings.

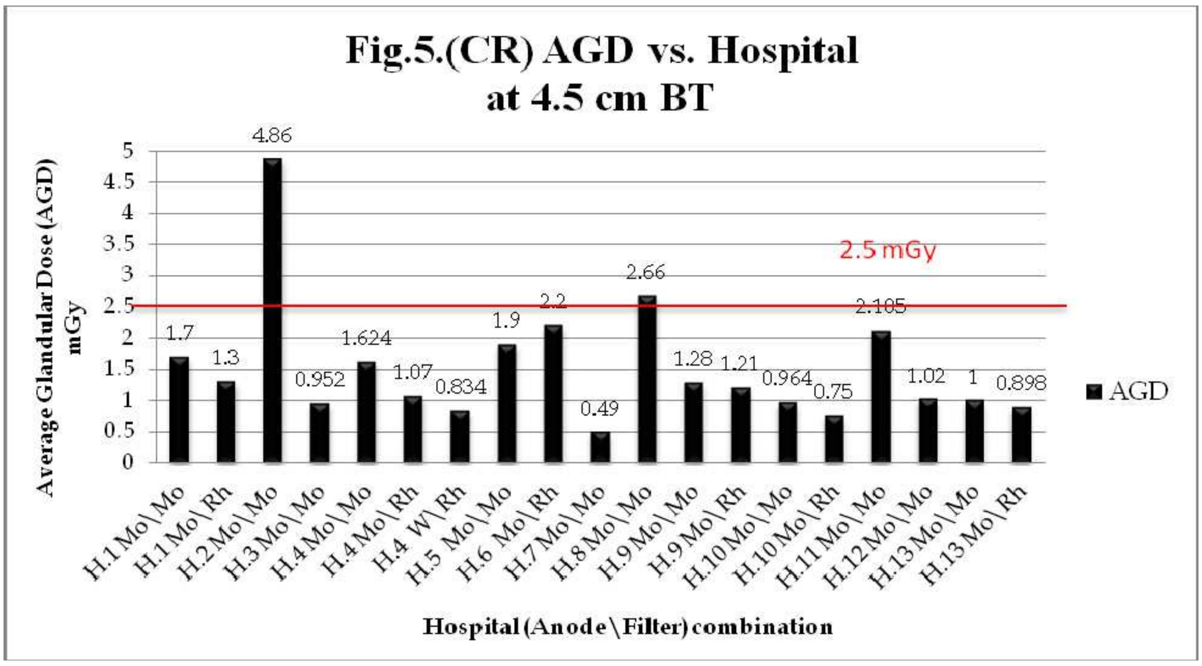


Fig. 5. ((CR) AGD vs. Hospital at 4.5 cm BT), shows that there was one hospital exceeding the acceptable dose limit (H2 Mo\Mo), the technician was use manual setting, they advise to call service to fix their machine. On the other hand we observe that (H7 Mo\Mo) have the lowest radiation dose to the patient, the technician were use manual setting for both KV & mAs.

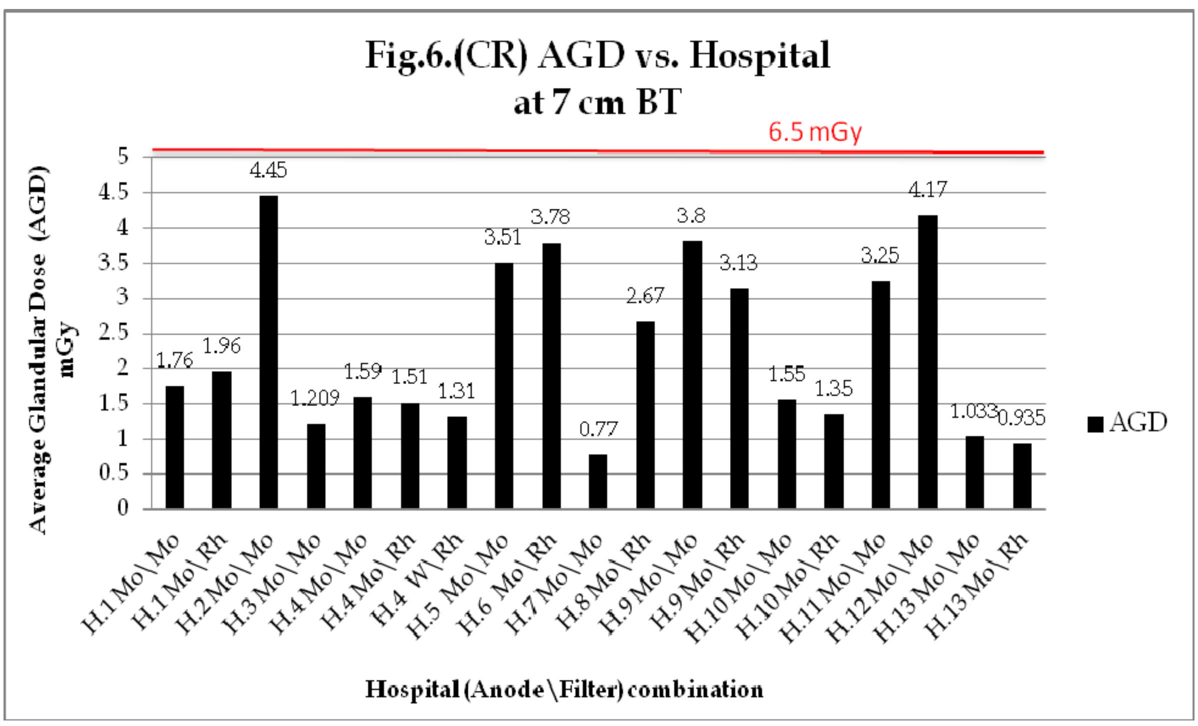


Fig. 6.((CR) AGD vs. Hospital at 7 cm BT),we observe that all hospital were below the AGD acceptable limit. As I explain before most of the hospital were using the manual settings for the Kv parameter. H7 Mo\Mo has the lowest radiation dose, the parameter that their use were so small Kv=27 & mAs= 50 the image quality was acceptable to their physician.

Results of the Three Screen Film Mammography machine

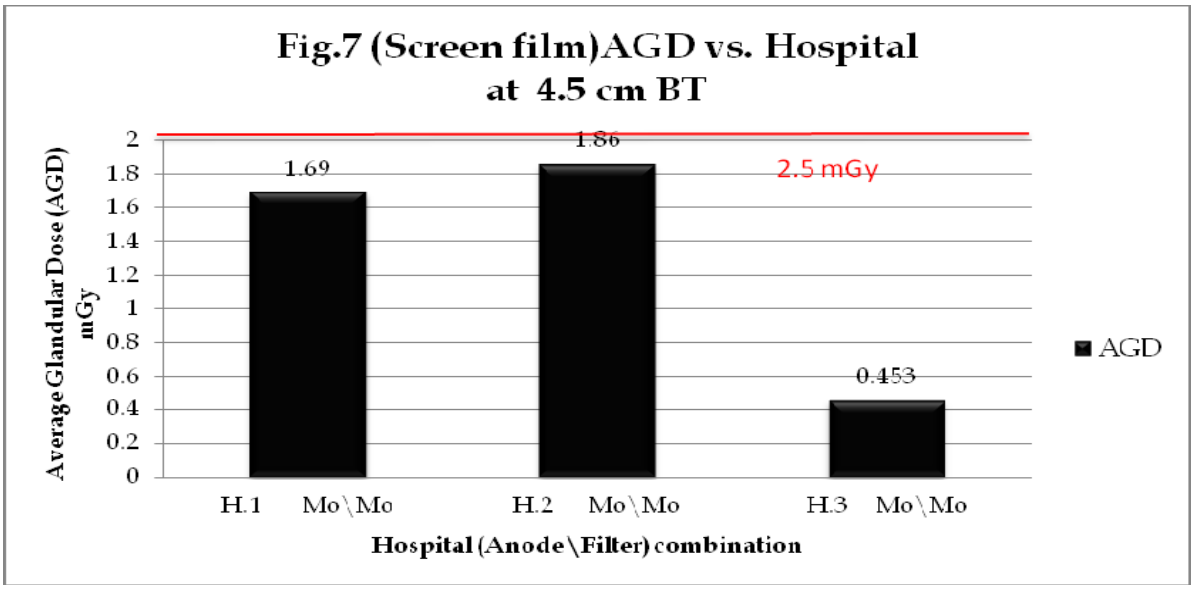


Fig. 7.((Screen film) AGD vs. Hospital at 4.5 cm BT), shows that all hospitals were below the AGD acceptable limit. All of these hospitals were using the manual setting for acquiring their images, their images were acceptable to their physician, for H3 the parameters used was Kv=28 & mAs=25.

Comparison between Calculated Average Glandular Dose (AGD) & System AGD

In most facilities, the difference between **AGD** values measured by the Physicist and those generated by the system were found acceptable, thus justifying a survey of patient doses on the basis of the AGD recorded by the system.

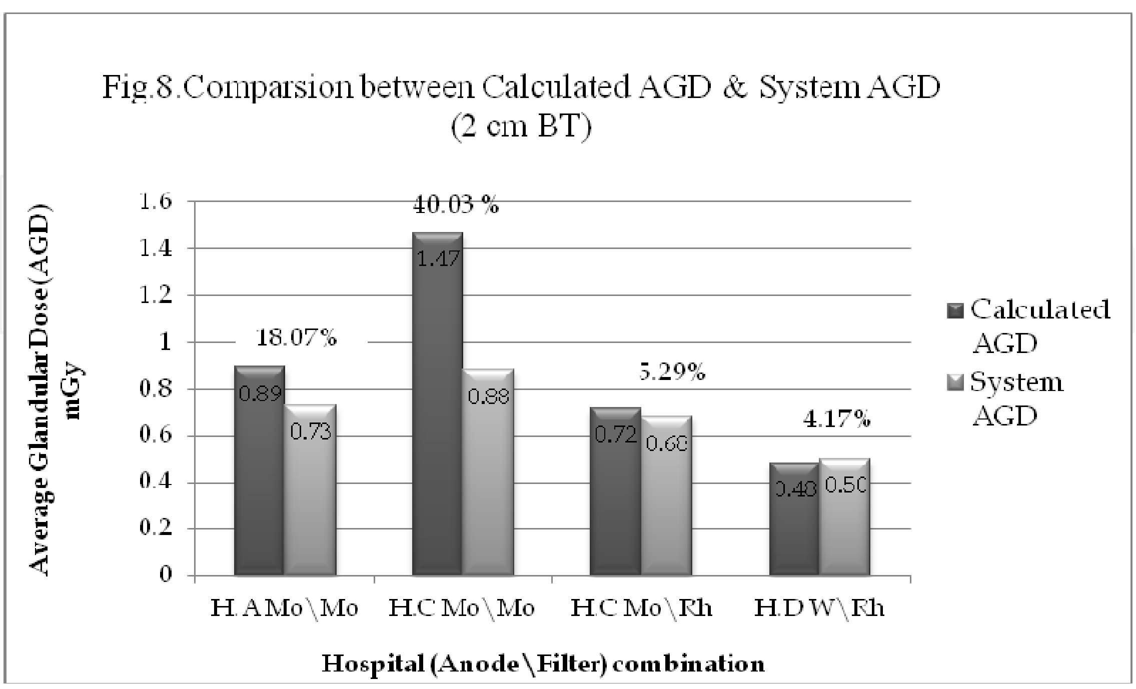


Fig. 8. Comparison between Calculated AGD & System AGD for 2 cm Breast Thickens.

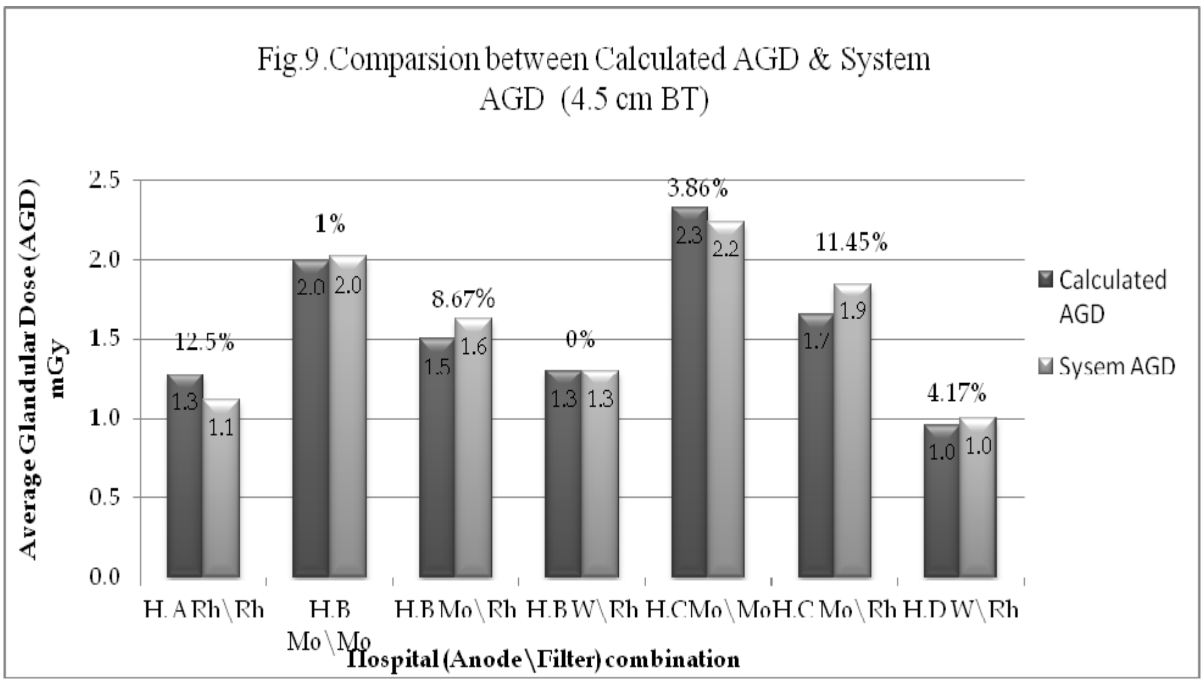


Fig. 9. Comparison between Calculated AGD & System AGD for 4.5 cm Breast Thickness.

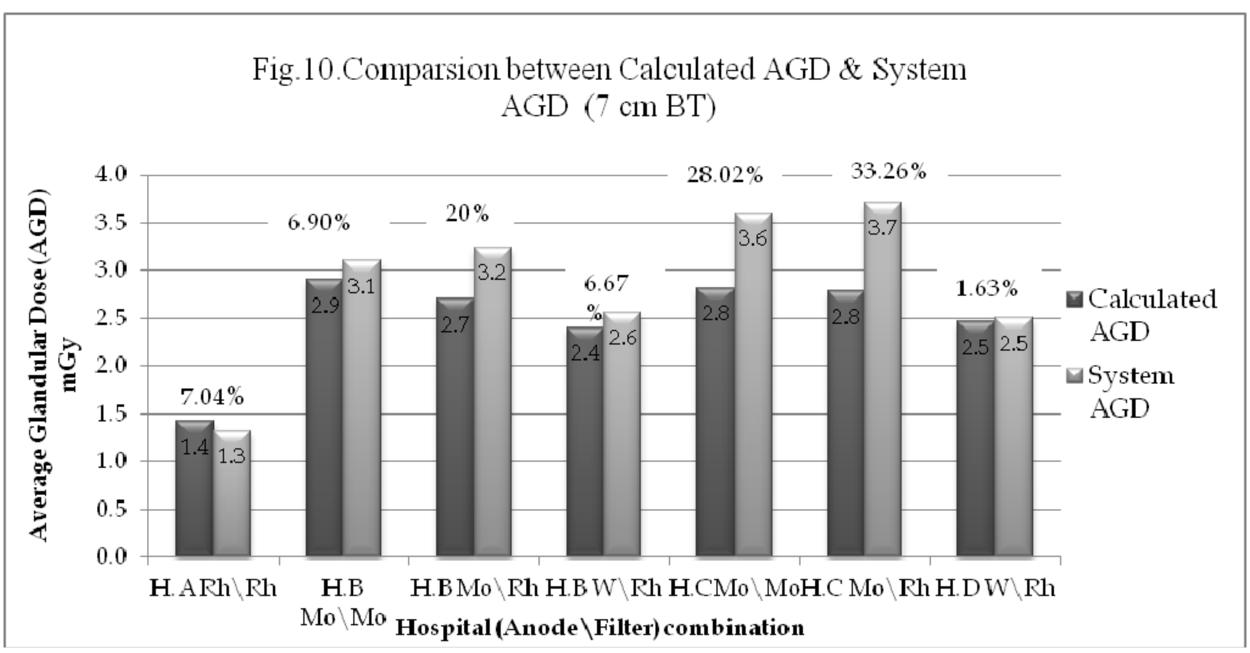
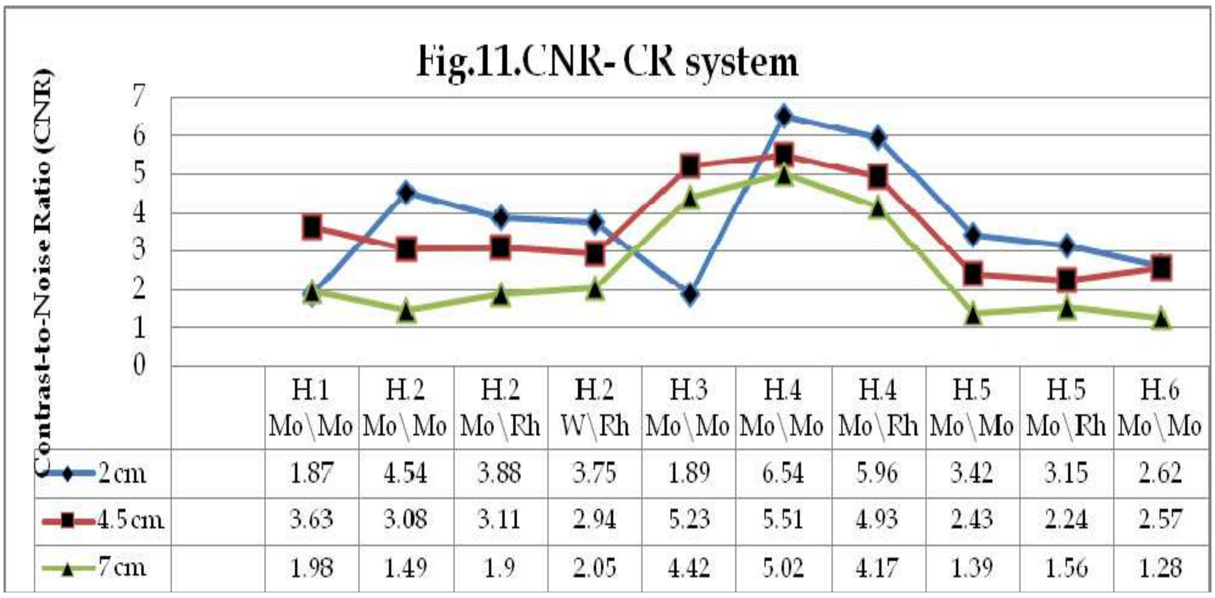


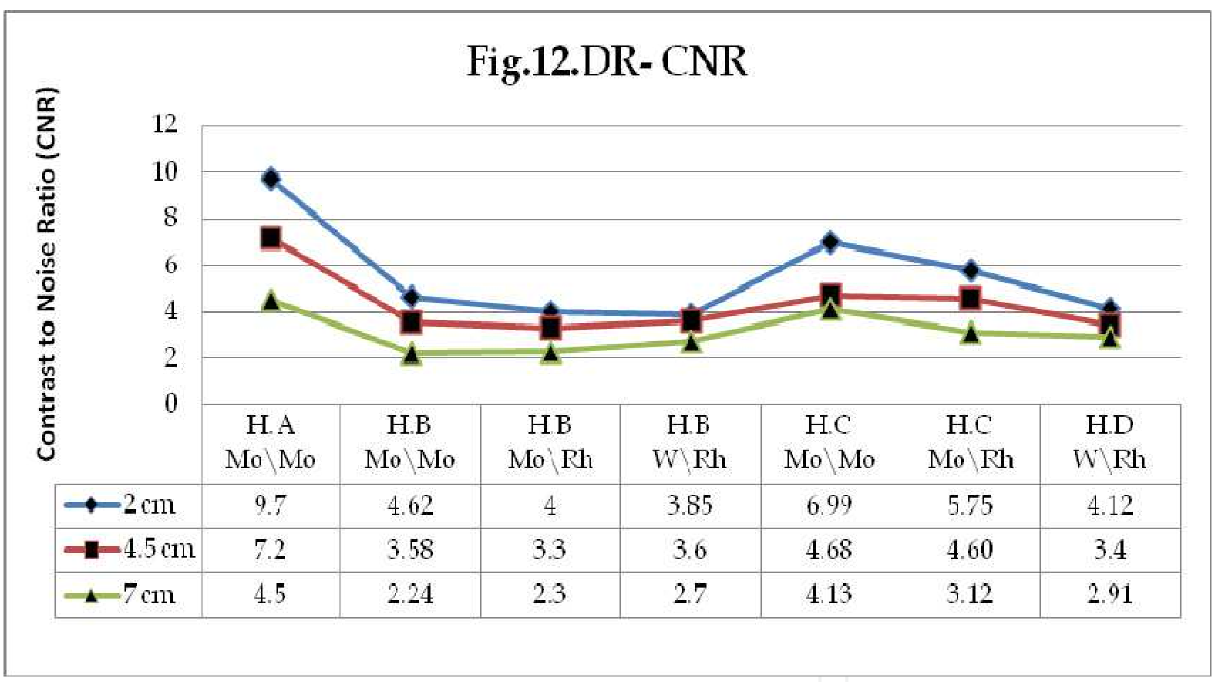
Fig. 10. Comparison between Calculated AGD & System AGD for 7 cm Breast Thickness.

Result of the Contrast to Noise Ratio results (CNR)



	H.1 Mo\Mo	H.2 Mo\Mo	H.2 Mo\Rh	H.2 W\Rh	H.3 Mo\Mo	H.4 Mo\Mo	H.4 Mo\Rh	H.5 Mo\Mo	H.5 Mo\Rh	H.6 Mo\Mo
2 cm	1.87	4.54	3.88	3.75	1.89	6.54	5.96	3.42	3.15	2.62
4.5 cm	3.63	3.08	3.11	2.94	5.23	5.51	4.93	2.43	2.24	2.57
7 cm	1.98	1.49	1.9	2.05	4.42	5.02	4.17	1.39	1.56	1.28

Fig. 11. the Contrast to Noise Ratio (CNR) –CR system.



	H.A Mo\Mo	H.B Mo\Mo	H.B Mo\Rh	H.B W\Rh	H.C Mo\Mo	H.C Mo\Rh	H.D W\Rh
2 cm	9.7	4.62	4	3.85	6.99	5.75	4.12
4.5 cm	7.2	3.58	3.3	3.6	4.68	4.60	3.4
7 cm	4.5	2.24	2.3	2.7	4.13	3.12	2.91

Fig. 12. the Contrast to Noise Ratio (CNR) –DR system.

4. Conclusion

This study on radiation exposure in mammography concerned number of facilities in Dubai region and will be extended to a larger number of facilities in the near future.

The results obtained show that quality control and patient Dosimetry are crucially needed in order to ensure a safe and efficient use of mammographic X-rays on patients whether for routine diagnosis or breast screening.

Also , we found that the value of the CNR is depend on the specification of the manufacture for each mammography machine , so we can't compare the value measured of the hospitals to each other because they are from different manufactures

5. Acknowledgment

- IAEA for initiating and supporting this project.
- Dubai Hospital Medical Physics Team.
- Dubai Health Authority (DHA)
- All hospitals participated in this project.

6. Appendix: The forms used to collect the data

Quality Control Findings – Mammography/ ------

Hospital: --- Done on: ------------------------

X-ray Tube	**Operation machine**
Manufacture: X-ray unit name: Model Number: Serial Number: Manufacture date:	Manufacture: Machine name: Serial Number: Manufacture date:

Exposure conditions

Radiographic projection:	Cranio-caudal/lateral/oblique		
Anode material:	Mo/W/Rh		
Inherent filtration material:			
Inherent filtration thickness:		mm	
Additional filtration material:			
Additional filtration thickness:		mm	
Focus to film distance:		cm	
Grid used:	Yes/No		
Automatic exposure control used:	Yes/No		
Tube potential: kVp ;	Tube charge: mAs		

Frequency: Acceptance, yearly and after tube or collimator repair/exchange.

6.1 Collimation assessment

Source to image receptor distance (SID) ---------- cm

Deviation between X-ray field and light field

Target material	Mo	Mo
Collimator (cm)	18x24	24x30
Left edge deviation		
Right edge deviation		
Sum of left and right edge deviations		
Sum as % of SID		
Anterior edge deviation		
Chest edge deviation		
Sum of anterior and chest edge deviations		
Sum as % of SID		

ACTION LIMIT: ACR/MQSA - If sum of left plus right edge deviations or anterior plus chest edge deviations exceeds 2% of SID, seek service adjustment.

Deviation between X-ray field and edges of the image receptor

Left edge deviation			
% of SID (retain sign)			
Right edge deviation			
% of SID (retain sign)			
Anterior edge deviation			
% of SID (retain sign)			
Chest edge deviation			
% of SID (retain sign)			

ACTION LIMIT: ACR/MQSA - If X-ray field exceeds image receptor at any side by more than 2% of SID or if X-ray field falls within image receptor on the chest wall side, seek service adjustment.

ACR - If X-ray field falls within image receptor by more than -2% on the left and right sides or by more than -4% on the anterior side, seek service adjustment.

Alignment of chest-wall edges of compression paddle and film

Difference between paddle edge and film					
Difference as % of SID					

ACTION LIMIT: ACR/MQSA -If chest-wall edge of compression paddle is within the image receptor or projects beyond the chest-wall edge of the image receptor by more than 1% of SID, seek service correction.

6.2 Kvp accuracy/reproducibility

KVp meter used-----------
Setting------/---------

	Set 1	Set 2	Set 3	Set 4
Nominal kVp setting				
Focal spot	L	L	L	L
Exposure time (sec)				
mA				
mAs	50	50	50	50

Measured kVp values

1					
2					
3					
4					
Mean kVp					
Standard deviation (SD)					
Mean kVp - Nominal kVp					
0.05 X Nominal kVp					
% Error					
Coefficient of variation					
Pass/Fail Results					
% Error Pass/Fail Criterion	5.00%	CV Pass/Fail Criterion			0.02

ACTION LIMIT: ACR/MQSA - If the mean kVp differs from the nominal by more than +5% of the nominal kVp, or if the coefficient of variation exceeds 0.02, then seek service correction.

6.3 Beam quality (HVL) measurement

Dosimetry system used-----------------

Nominal Kvp setting	30	30	30
Target material			
Filter			
mA			
Time			
mAs	50	50	50
No aluminum filtration, E(0a)			
0.2 mm of added aluminum, E(2)			
0.3 mm of added aluminum, E(3)			
0.4 mm of added aluminum, E(4)			
0.5 mm of added aluminum, E(5)			
0.6 mm of added aluminum, E(6)			
No aluminum filtration, E(0b)			
Average E(0)			
Average E(0)/2			
Calculated HVL (mm Al)			

MQSA X-Ray Tube Voltage and Minimum HVL	
Measured Voltage (kV)	Minimum HVL (mm Al)
20	0.2
25	0.25
30	0.3

6.4 Image quality

Using ACR Phantom:
Anode/Filter: ---------------------
The exposure factors were kV= mAs= ESAK= AGD=

NO.	**Region Materials**	**Visible**
1	1.56 mm nylon fiber	
2	1.12 mm nylon fiber	
3	0.89 mm nylon fiber	
4	0.75 mm nylon fiber	
5	0.54 mm nylon fiber	
6	0.40 mm nylon fiber	
7	0.54 mm simulated micro-calcification	
8	0.40 mm simulated micro-calcification	
9	0.32 mm simulated micro-calcification	
10	0.24 mm simulated micro-calcification	
11	0.16 mm simulated micro-calcification	
12	2.00 mm tumor-like mass	
13	1.00 mm tumor-like mass	
14	0.75 mm tumor-like mass	
15	0.50 mm tumor-like mass	
16	0.25 mm tumor-like mass	

6.5 Using TOR MAX phantom

Anode/Filter: ---------------------
BT = 2cm, Exposure factor: kV= mAs= ESAK= AGD=
BT = 4.5cm, Exposure factor: kV= mAs= ESAK= AGD=
BT =7cm, Exposure factor: kV= mAs= ESAK= AGD=

Unsharpness Measurements:

Resolution Limit	RHS Grating	BT	Groups	Line pairs/mm
		2		
		5		
		7		
	LHS Grating	BT	Groups	Line pairs/mm
		2		
		5		
		7		
Low Contrast Bar Patterns		BT	Groups	Line pairs/mm
		2		
		5		
		7		

Low Contrast Sensitivity:

	BT	No. detected	Threshold Contrast
1.6 mm details:	2		
	5		
	7		

Small Detail Visibility:

	BT	No. detected	Threshold Contrast
0.5 mm details:	2		
	5		
	7		
0.25 mm details:	BT	No. detected	Threshold Contrast
	2		
	5		
	7		
Particle Stepwedage :	BT	Comment	
	2		
	5		
	7		

6.6 Contrast to noise ratio measurement

Exposure conditions

Radiographic projection:		Cranio-caudal
Anode material:	Mo/W/Rh	
Inherent filtration material:		
Inherent filtration thickness:		mm
Additional filtration material:		
Additional filtration thickness:		mm
Focus to film distance:		cm
Grid used:	Yes/No	
Automatic exposure control used: Yes/No		

$$CNR = \frac{S_{AL} - S}{\sqrt{(\sigma_{AL}^2 + \sigma^2)}}$$

PMMA (cm)	Anode /Filter	kV	mAs	AGD (mGy)	Under Al object S_{al}	SD_{al}	Side to Al object **S**	**SD**	CNR
2									
3									
4									
4.5									
5									
6									
7									
ACR Phantom									

6.7 Dose measurement

CBT = 2 cm

Exposure conditions

Focus-Chamber Distance (cm):
FBD Focus-Bucky Distance (cm):
${}_nK_i$ @FBD = K_i (FCD/FBD)^2 /mAs ${}_nK_e$=${}_nK_i$*BF

Note, BF=1.09; K_i should be correct for calibration factors, temperature and pressure

Anode/Filter	kV		mAs		Reading K_i (mGy)	${}_nK_i$/mAs @ FBD (mGy/mAs)	${}_nK_e$ (mGy/mAs)
	Auto	Manu	Auto	Manu			

ESAK calculation for clinical exposures
K_e=${}_nK_e$*mAs*(FBD/(FBD-BT))^2
Note: use proper ${}_nK_e$ for the used anode/filter combination

BT Breast thickness (cm)	Focus-Breast Distance (cm)	Anode/Filter	kV	mAs	Ke @FBD (mGy)	Ke (mGy/mAs)

7. References

AAPM Report No. 29, Equipment Requirements and Quality Control for Mammography, August 1990

IAEA Group Training on Radiation Protection dose assessment and dose management in Diagnostic and Interventional Radiology, 7-18 May 2008, Udine (Italy)

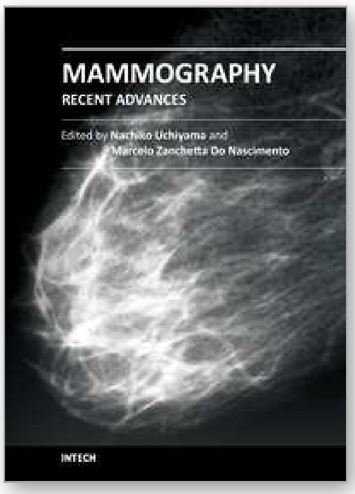
IAEA-TECDOC-1447, Optimization of the radiological protection of patients: Image quality and dose in mammography (coordinated research in Europe), May2005

Journal of the ICRU Vol. 5 No 2 (2005) Report 74- Oxford University Press, Chapter 3 – Quantities and Units for Measurement and Calculation in Medical X-Ray Imaging.

N.Perry, M. Broeders, C. de Wolf, S. Törnberg, R. Holland & L. von Karsa - 4th edition of the European Guidelines for Quality Assurance in Breast Cancer Screening and Diagnosis (EUREF) – Office for Official Publications of the European Communities, 2006

Nuclear Associates 18-220, Mammographic Accreditation Phantom, Instruction Manual© 2003 Cardinal Health, Inc. www.cardinal.com/rms

Priscilla F. Butler, M.S, Digital Mammography Quality Control and Accreditation, (July 1, 2006)



Mammography - Recent Advances

Edited by Dr. Nachiko Uchiyama

ISBN 978-953-51-0285-4

Hard cover, 418 pages

Publisher InTech

Published online 16, March, 2012

Published in print edition March, 2012

In this volume, the topics are constructed from a variety of contents: the bases of mammography systems, optimization of screening mammography with reference to evidence-based research, new technologies of image acquisition and its surrounding systems, and case reports with reference to up-to-date multimodality images of breast cancer. Mammography has been lagged in the transition to digital imaging systems because of the necessity of high resolution for diagnosis. However, in the past ten years, technical improvement has resolved the difficulties and boosted new diagnostic systems. We hope that the reader will learn the essentials of mammography and will be forward-looking for the new technologies. We want to express our sincere gratitude and appreciation?to all the co-authors who have contributed their work to this volume.