International Journal of Science and Technology

http://www.ejournalofsciences.org

Inter-Comparison of Dose Indicators and Mean Glandular Dose for some Selected Diagnostic Mammography Units in Accra, Ghana

E. Akrobortu[1] *, M. Boadu[2], J. Yeboah[1], C. Schandoff [3] and P. K. Gyekye[1]
[1]Ghana Atomic Energy Commission, Radiation Protection Institute,
P. O. Box LG 80, Legon, Accra
[2]Ghana Atomic Energy Commission, Radiological and Medical Sciences Research Institute,
P. O. Box LG 80, Legon, Accra
[3]University of Ghana, School of Nuclear and Allied Sciences, Department of Nuclear Safety and Security,
P.O. Box AE 1, Atomic, Accra, Ghana

ABSTRACT

Quality assurance programmes on three (3) mammography units located in Accra have been carried out using standard performance criteria. Darkroom quality control and a number of quality control tests with respect to: tube voltage accuracy and reproducibility, radiation output linearity and consistency, mean glandular dose (MGD) were assessed for each unit. MGD estimated from free in air measurements were found to be 0.32-1.45 mGy, 0.33-1.30 mGy and 1.05-2.70 mGy with grid for facilities A, B and C respectively using a standard breast thickness of 45 mm. The performance criteria of key quality control parameters were found to be within acceptable limits except base + fog and contrast index of radiographic films.

Keywords: *Mammography, Quality Assurance, Quality Control, Mean Glandular Dose*

I. INTRODUCTION

Mammography techniques are widely utilised in medical diagnosis when a functional study of the anatomy of the female breast is required. During mammography examinations, patients are exposed to low energy x-rays at 25 to 28 peak kilo voltage (kVp) [1, 2]. Additionally, the procedure involves the use of specialised screen-film imaging system to deliver low doses to patients. The specialised screen film includes single thin intensifying screen and single emulsion film. The optimised screen- film system ensures that the image sharpness is maximised with high contrast or spatial resolution [1, 2]. Optimisation of mammographic procedures in hospitals must be ensured in order to reduce radiation doses to patients whilst achieving the optimum quality image.

In mammography, the type of results needed determine the examination performed. Either screening or diagnostic mammography is employed. Screening mammography is carried out on age-appropriate asymptomatic women in order to detect unsuspected breast cancer. This is done to reduce breast cancer mortality rate [3]. Diagnostic mammography is radiographic examination that provides additional information about a patient with clinically detected breast abnormalities. It is intended for specific analytic evaluation [3]. Additional studies with ultrasound and magnetic resonance imaging may be used for breast abnormality detection.

The carcinogenic risk associated with absorbed radiation dose to the breast is a matter of concern. In order for a quality diagnostic image i.e. high contrast and resolution to be obtained with minimal associated carcinogenic risk, high quality assurance programme is essential. The quality assurance programme in any facility should comprise basic principles of training, specialisation, multi-disciplinary team work, the use of set targets, performance indicators and audits [3].

The assessment of doses and image quality from mammographic examinations has been complex due to the dynamic and demanding nature of the examinations. In a single examination, a number of factors such as the breast thickness, composition, film processing unit, the beam quality, breast compression device and geometry of the imaging system are considered [4].

It is widely considered that breast cancer can be induced by high doses of ionising radiation, such as x-rays, and the probability of induction is dose dependent [5, 6]. There should, therefore, be strict adherence to provisions concerning the quality and safety of mammography diagnosis and screening tests involving exposure to radiation so as to minimise the probability of any adverse effect occurring. The mammographic examination must be justified; with the benefits out weighing any risk arising from the associated radiation that may induce breast cancer [7]. Mammography procedure should be performed on appropriate age specific, asymptomatic women with provisions made for those outside the specific age range.

The study focused on the three major referral hospitals in the Greater Accra region. Quality control on the three (3) hospitals' mammography unit was performed and inter-compared for continuous improvement since optimisation of procedures under radiation exposure is very paramount.

II. MATERIALS AND METHODS

These study was carried out at facilities A, B and C all in Accra, Ghana using Siemens Mammomat C3 (serial number A102188), Senographe 700T (serial number 00000086637TX6) and Siemens 300 (serial number 6088806X041E), mammography equipment respectively with grid. In all, 300 patients (100 patients from each facility) were selected at random for the mean glandular dose (MGD) estimation. Mammography screening and diagnostic examinations were performed by specialist (radiologists) and qualified radiographers at the respective Hospitals.

Mammographic Unit Quality Control Measurements

The output measurement (consistency and linearity), tube voltage accuracy and reproducibility of the mammography equipment were checked for all the Hospitals using Unfors Xi ionisation chamber (serial number: 132895), by employing the standard procedure as given in the America College of Radiology Mammography Quality Control Manual [8], and the European Protocol for the Quality Control of the Physical and Technical Aspects of Mammography document [9].The output linearity was checked for compliance with acceptance criteria of ≤ 0.1.

The half value layer (HVL) of an x-ray beam is described by the thickness of a reference material that would reduce the intensity or exposure rate of the beam by one-half, [10, 11] for that matter, the beam quality (half value layer) was determined using standard set of aluminium filters with thickness between 0.10 mm and 0.20 mm and the Unfors Xi ionisation chamber (serial number: 132895). The HVL was estimated using equation 1.

$$HVL = \frac{X_1 In\left(\frac{2Y_2}{Y_0}\right) - X_2 In\left(\frac{2Y_1}{Y_0}\right)}{In\left(\frac{Y_2}{Y_1}\right)} \qquad (1)$$

Where: Y_0 denotes the direct exposure reading in mGy, Y_1 is the exposure reading that is just greater than one-half of Y_0 and X_1 the corresponding aluminium thickness, Y_2 is the exposure reading that is just less than one-half of Y_0 and X_2 the corresponding aluminium thickness [13]. The HVL was determined for the entire tube voltage range of each facility.

Darkroom Quality Control

The temperature of the darkroom, developer and fixer were measured using TM99A Electro-thermo digital thermometer (serial number: C354843). Glass thermometer was not used so as to avoid contamination risk in the event of breakage. A film was exposed to light using X-Rite sensitometer (serial number: 02404) to determine photographic parameters such as Base + fog, speed index, and contrast index using X-Rite densitometer (serial number: 331). This was done to assess and evaluate the image processing system at each facility.

Dose Assessment

Free in air measurements with the Unfors Xi ionisation chamber (serial number 132895) placed at 63 cm from the x-ray tube were made, varying tube voltage (kV) and current-time product (mAs). The output (mGy/mAs) was obtained and plotted against the corresponding kV to obtain an entrance surface air kerma curve [12]. With a known exposure kV per examination, the output (mGy/mAs) at 63 cm was obtained from the curve. The entrance surface air kerma (ESAK) was estimated using equation 2 with a known focus to skin distance (FSD) and mAs per examination.

$$ESAK_{(kVp,mAs)} = [Y \times Q/(FSD)^2] \qquad (2)$$

Where: Y is the output ($Y = a \times kV^b (mGy\ m^2/mAs)$); a and b are the fit parameters with k being a constant [11] and V is the kVp. Q is the product of tube current and exposure time.

The Mean Glandular Dose (MGD) is the product of ESAK and the conversion factors, p and g. The conversion factor, p, convert air kerma for a Perspex phantom to that of a standard breast and g, converts air kerma for a standard breast to mean glandular dose. The MGD was obtained using equation 3 as shown below [5].

$$MGD = Kpgs \qquad (3)$$

Where: s, is the factor for the relevant target filter combination [5, 13] and K is the ESAK. The MGD was estimated for the four projections i.e. left and right cranio-caudal, and left and right medio-lateral oblique. The results were compared with other studies done using Perspex phantom.

III. RESULTS AND DISCUSSION

Tube voltage accuracy checked for the three mammography units have been presented in Table 1. The energy level of the photons for the nominal and the measured kVp varied. The tube voltage percentage deviations were all within the acceptable percentage deviation of 5 % [13]. Comparatively, facility B recorded the highest tube voltage percentage deviation whilst facility A recorded the lowest tube voltage percentage deviation.

Table 2 shows the coefficient of variation (CV) obtained for the kVp reproducibility test performed for the three mammography units. The CVs for the three mammography units were all below the allowable CV of 0.02 (2%) [13]. Comparatively, facility B recorded the lowest CV i.e. the kVp of facility B mammography unit is more reproducible than the other two mammography units.

Radiation output consistency and linearity for the three mammography units have been presented in Table 3a and 3b respectively. The mammography exposure outputs for all the units were found to be consistent and the output

linearity values (OLV) were less than the acceptable criterion of 0.01 (10 %) [13]. Generally, the output ratio (mGy/mAs) obtained for all the units at the same kVp recorded higher value for facility C comparatively. At the most clinically used kVp of (28), the radiation output from the mammography unit at facility A is more linear comparatively. At 30, 32 and 34 kVp, the mammographic unit output for facilities A, C and B is more linear respectively.

The HVL for kVp range of 26 - 34 for the three mammography units are presented in Table 4. At any kVp, the HVL for all the three mammography units were acceptable. Comparatively, the HVL for facility B at any kVp is higher than that of A and C. It can therefore be inferred that the radiation beam of the mammography unit at B is more penetrating than the others.

MGD with grid estimated from the study has been compared with diagnostic reference levels (DRL) from internationally recognised organisations as presented in Table 5. Generally, the MGD values for the three units decreases with increasing kVp. Comparatively, the MGD for facility C is higher than that of A and B. This could be attributed to the high radiation output of facility C mammography unit. None of the MGD for all the units was more than the DRL for IPSM and NRPB. MGD for facility C at 25 and 27 kVp were found to be higher than the DRL for AAPM.

Table 6 shows film characteristics and darkroom temperature for all the three facilities considered. The Base + Fog index was found to deviate from the acceptable criterion [8, 13] for facility A and B radiographic films but was within the acceptable criterion for that of facility C radiographic film. The speed index for all the facilities were found to be within the acceptable criterion [8, 13]. The contrast index for facilities A and B were also within the acceptable criterion [8, 13] but that of facility C deviated by a factor of 0.60.

Agfa radiographic films are employed by all the facilities for radiographic image production. The recommended temperature for storage as specified by the manufacturer is 21^{o}C. However, the darkroom where the radiographic films are stored for all the facilities, recorded high temperature readings. This could be the reason why the base + fog and the contrast index deviated from the acceptable criterion in some facilities.

IV. CONCLUSIONS

The kVp accuracy for all the units was within the acceptable criterion with that of A being more accurate than the rest of the units. The kVp reproducibility was found to be within the allowable coefficient of variation (CV), with facility A mammography unit being better kVp reproducible than the other units. The output measurements for the three units were found to be consistent with that of facility C recording higher values than the other units at a given kVp. Comparatively, at the clinically used kVp of 28, facility A's output was found to be more linear than the others. The HVLs at the respective kVp were found to be within the acceptable criterion for all the units but comparatively, facility B had more penetrating beam than the others.

MGD for all the units was found to be below IPSM and NRPB DRLs except AAPM at 25 kVp and 27 kVp. Comparing the estimated MGD among the units, facility C recorded high MGDs than the others due to the high radiation output. The MGD was observed to decrease with increasing kVp and further study in the relationship is required. The darkroom temperatures should be regulated to improve upon the resolution and contrast of films. Quality assurance programme in the hospitals should be maintained to provide adequate confidence that an item, process or service will satisfy given requirements for quality, thereby, reducing the occurrence of stochastic effects and preventing deterministic effects in patients.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to Mr. Boateng (The Chief Radiographer at facility A), Miss. Josephine Nkansah at facility B, and Lt. Col. (Dr.) Andrews Kaminta (Radiologist), Captain Mintah and Corporal Owira Danso all at facility C and all other staff at the various mammography units for their help in the collection of the data.

Our gratitude also goes to Prof. Cyril Schandorf, Prof. Geoffrey Emi-Reynolds, Prof. Emmanuel. O. Darko, Dr. Joseph Amoako and Dr. Augustine Faanu for their immense support.

REFERENCES

[1]. Breast Cancer Campaign. *The History of Breast Cancer*. (Available at http//:www. breastcancercampaign.org). Last accessed in April, 2012.

[2]. European Society of Mastology (EUSOMA). *Quality Assurance in the Diagnosis of Breast Cancer*. European Journal of Cancer, 37: 159-172, (2001).

[3]. American College of Radiology (ACR). *Practice Guideline for the Performance of Screening and Diagnostic Mammography*. Resolution 24. (2008). (Available at http://www.acr.org/ secondarymainmenucategories/quality_safety/guidelines/breast/screening_diagnostic.aspx.). Last assessed on March, 2012.

[4]. American Association of Physicists in Medicine (AAPM). *Equipment Requirements and Quality Control for Mammography*. Report 29. American Institute of Physics, New York. (1990).

[5]. Institute of Physical Sciences in Medicine (IPSM). *The Commissioning and Routine Testing of Mammographic X-ray Systems*. IPSM Topical Group Report 59, IPSM, York. 2nd edn (1994).

[6]. Hammerstein, G.K., Miller, D.W. and White, D.R. *Absorbed Radiation Dose in Mammography*. Radiology; 130: 485-491(1979).

[7]. International Commission on Radiological Protection (ICRP). *Recommendations of International Commission on Radiological Protection.* Publication 103 (Elsevier Science, 1st Edition) (2008).

[8]. American College of Radiology (ACR). *Mammography Quality Control Manual*. ACR: Reston, VA (1999).

[9]. Health and Consumer Protection Directorate General. *European guidelines for quality assurance in breast cancer screening and diagnosis: The European Protocol for the Quality Control of the Physical and Technical Aspects of Mammography Screening*. Luxembourg: Office for Official Publications of the European Communities. 4th edn. ISBN 92-79-01258-4. (2006).

[10]. Klein, R., Aichinger, H., Dierker, J., Jansen, J. T., Joite-Barfuss, S., Sabel, M., Schulz-Wendtland, R., and Zoetelief, J. *Determination of average glandular dose with modern mammography units for two large groups of patients.* Phys. Med. Biol; 429 (4): 651-71, (1997).

[11]. Dance, D.R. *Monte Carlo Calculation of conversion coefficients of mean glandular dose*. Phys. Med. Biol. 35 1211-1222, (1990).

[12]. Dance, D.R., and Day, G.J. *The Computation of Scatter in mammography by Monte Carlo methods.* Phys. Med. Biol. 29, 237-47, (1984).

[13]. International Atomic energy Agency (IAEA). *Quality Assurance Programme for Screen Film Mammography*. IAEA-Human Health Series No. 2. (2009). (Available at http://www.iaea.org/publication/index-html). Last assessed in April, 2012.

[14]. National Radiological Protection Board (NRPB). *Guidelines on patient dose to promote optimization of protection for diagnostic medical exposure.* Document of NRPB 10(1) (1999).

Table 1: Comparison of kVp accuracy results of the three mammography units with percentage uncertainties of measured data

Nominal kVp	Measured kVp		
	A	B	C
26	25.28 ± 2.8	26.85 ± 3.3	27.15 ± 4.4
28	28.90 ± 3.2	29.13 ± 4.0	29.20 ± 4.3
30	30.05 ± 0.2	31.20 ± 4.0	31.10 ± 3.7
32	32.80 ±3.0	33.35 ± 4.2	32.85 ± 2.7
34	35.40 ± 4.1	35.38 ± 4.2	32.40 ± 4.1

Values represented as mean ± percentage deviation

Table 2: Coefficient of variation of kVp reproducibility for the three mammography units

Nominal kVp	Coefficient of Variation		
	A	B	C
26	0.0075	0.0022	0.0037
28	0.0089	0.0017	0.0001
30	0.0064	0.0001	0.0001
32	0.0058	0.0030	0.0024
34	0.0023	0.0014	0.0034

Table 3a: Output Consistency results of the three facilities

Nominal kVp	mAs	Output Consistency (mGy/mAs)		
		A	B	C
28	50	0.1194	0.1176	0.1674
28	50	0.1198	0.1178	0.1679
28	50	0.1196	0.1172	0.1673
30	50	0.1480	0.1452	0.2067
30	50	0.1480	0.1446	0.2064
30	50	0.1484	0.1446	0.2069
32	50	0.1770	0.1746	0.2503
32	50	0.1769	0.1738	0.2499
32	50	0.1772	0.1730	0.2506
34	50	0.2141	0.2060	0.2954
34	50	0.2135	0.2056	0.2963
34	50	0.2130	0.2060	0.2959

Table 3b: Output Linearity results of the three facilities

Nominal kVp	mAs	Output Linearity Value (OLV)		
		A	B	C
28	50	0.0017	0.0019	0.0020
28	50			
28	50			
30	50	0.0013	0.0022	0.0014
30	50			
30	50			
32	50	0.0012	0.0044	0.0011
32	50			
32	50			
34	50	0.0025	0.0012	0.0015
34	50			
34	50			

Table 4: Comparison of Beam Quality (Half Value Layer) results of the three mammography units

Nominal kVp	Half Value Layer (mmAl)			
	A	B	C	Accepted criterion (≥) [8]
26	0.33	0.36	0.33	0.29
28	0.37	0.40	0.35	0.31
30	0.38	0.42	0.39	0.33
32	0.40	0.43	0.40	0.35
34	0.42	0.45	0.43	0.37

.

Table 5: Comparison of MGD with grid from this study with work done by other researchers

Nominal kVp	Mean Glandular Dose (mGy)					
	This Study			IPSM (1994) [5]	AAPM (1990) [4]	NRPB 1999 [14]
	A	B	C			
25	1.45	1.30	2.71			
27	0.99	1.02	2.16	3.00	1.80	3.00
28	0.65	0.61	1.60			
30	0.38	0.46	1.30			
32	0.32	0.33	1.05			

Table 6: Comparison of radiographic film characteristics of an Agfa film and the darkroom temperature for all the facilities

	Optical Density			
	Base +Fog Index	Speed Index	Contrast Index	Darkroom Temperature (^{0}C)
A	0.25	1.10	1.87	25.50
B	0.28	1.22	1.80	26.50
C	0.20	1.32	1.15	25.90
[a]Accepted criterion [8,13]	0.18± 0.03	1.20 ± 0.15	1.75 ± 0.15	21.00

[a]Values represented as original value ± allowable deviation.