East Africa Medical Journal Vol. 88 No. 11 November 2011
ASSESSMENT OF PATIENT DOSES DURING MAMMOGRAPHY PRACTICE AT KENYATTA NATIONAL HOSPITAL
J. S. Wambani, MBChB, MMed (Rad.) Chief Medical Specialist, Radiology, Department of Paediatric Radiology, Kenyatta National Hospital, P. O. Box 20723-00202, Nairobi, Kenya, G. K. Korir, BSc, MSc, (Nuc.Sci), MSc(Rad. Sci), Department of Physics and Applied Physics, University of Massachusetts Lowell, One University Avenue, Lowell, MA 01854, M. N. Shyanguya, Bwonya, Dip. RAD(D) HND (U/S), Deputy Chief Radiographer, Department of Radiology, Kenyatta National Hospital, P. O. Box 20723-00202, Nairobi, Kenya, and I. K. Korir, BSc, MSc, PhD. Senior Specialist-Nuclear Engineering National Nuclear Regulator, Eco Glades 2 Office Park, Block G, Eco Park, Centurion, 0157 South Africa

Request for reprints to: Dr. J. S. Wambani, Department of Paediatric Radiology, Kenyatta National Hospital, P. O. Box 20723-00202, Nairobi, Kenya

ASSESSMENT OF PATIENT DOSES DURING MAMMOGRAPHY PRACTICE AT KENYATTA NATIONAL HOSPITAL

J. S. WAMBANI, G. K. KORIR, M. N. SHIYANGUYA BWONYA and I. K. KORIR

ABSTRACT

***Objective*: To evaluate the average glandular dose (AGD) in mammography for cranio-caudal (CC), medio-lateral oblique (MLO) projections and the dose per woman.**
***Design*: The average glandular dose, device performance, viewing box tests and image quality grading were carried out at the largest mammography facility in Kenya.**
***Setting*: Radiology Department at Kenyatta National Hospital (Referral, teaching and research hospital in Kenya.)**
***Subjects*: A questionnaire method was developed and used in recording the patient dose, compressed breast thickness (CBT), exposure factors, luminance of the viewing boxes, room luminance levels and image quality.**
***Results*: There were 3264 films from 1252 women of between 25 to 90 years old. The AGD per film was 2.14 mGy (range 0.27-9.43 mGy) for the CC projection and 2.44 mGy (range 0.20-10.12 mGy) for the MLO projection. 17% of CC films and 30% of MLO films recorded doses above the 3 mGy diagnostic reference level.**
***Conclusion*: The variation of mammography imaging techniques and doses revealed the need for National Standards in mammography practice in Kenya.**

INTRODUCTION

Kenya has a population of about 40 million people with women constituting 51.8% (1). Communicable diseases still pose the biggest challenge, but currently the incidence of non-communicable diseases is on the increase. Cancer ranks third as a major cause of death in the country after infectious diseases such as HIV and cardiovascular diseases. There are over 11,000 cancer incidences reported annually of which 53% are women and 47% are men. Breast cancer constitutes 21% of all cancer cases and ranks third according to cancer type. It is the second highest cause of cancer deaths in females after cervix uteri cancer (2). Neither the real cause of cancer nor effective method of prevention is known. Breast cancer starts in the terminal ducts of the breast. In the pre-invasive stage, the cancer cells are confined to the ducts system. This is followed by the invasive stage where cancerous cells infiltrate into the surrounding tissues including the lymph nodes.

Mammography is a powerful radiographic imaging technique for detecting and managing breast cancer. Therefore, mammography remains one of the best early (small) malignant breast cancer detection methods, that leads to effective management and improved prognosis. However, it may also increase radiation induced carcinogenesis. The active and radiosensitive glandular tissue has tissue-weighting factor of 0.12 indicating that the breast is one of the most radiosensitive organ in the body (3). For this reason optimal equipment performance and dose management per mammogram is essential.

Kenya has no established breast cancer screening programs and coupled with inadequate diagnostic radiology and laboratory services in most health facilities has led to late cancer detection rate. A high number of breast cancer patients therefore present with advanced disease. Effective breast cancer treatment is associated to the lesion size and the status of the lymph nodes. Radiotherapy treatment with technologically advanced equipment and skilled manpower are among the available treatment methods which have improved the survival rate of cancer patients across the world. However, utilisation of this technology is low in developing countries due to the exorbitant costs of therapy and late stage of disease presentation.

Mammography is performed by qualified personnel using dedicated x-ray equipment to detect clinically unsuspected breast lesions. The first mammography equipment to be installed in Kenya dates back to 1990. There has been an increase in the availability of mammography equipment with a present tally of nineteen facilities countrywide. There is no quality assurance programme in place for the regular assessment of image quality and patient doses in these facilities. The challenges faced include high level of expertise required, imaging of dense glandular breasts as well as differentiating presentation of benign or malignant tissues. This requires a higher level of quality assurance programme involving specific tests on the mammography x-ray unit, image quality assessment, consistency tests, and radiation dose measurement. In a set up of a skilled imaging technologist, a radiologist, breast surgeons and pathologist, mammograms of good diagnostic quality are useful tools in the early detection of cancer and provision of better quality of life for the affected individuals.

In Kenya, the use of mammography encompasses the examination of symptomatic women, diagnosis of symptomatic patient and monitoring of breast cancer. There is neither a national screening programme nor published information in the literature on radiation dose due to mammography practice. To manage cancer, the country needs to enhance early detection, adopt possible preventive measures and develop individualised cancer therapies. Although there is a government plan to implement mammographic imaging system on the national scale, there is no recommendation or restrictions regarding age or frequency of mammography examinations for self referred individuals. This study was initiated to address this need and to enhance effective optimisation of mammography practice in the country. The aim of the study was to assess the level of equipment performance, imaging protocols and radiation dose to patients undergoing mammography.

MATERIALS AND METHODS

A descriptive study to assess the quality of mammography diagnosis was carried out over a period of one year at the referral hospital based in the capital city of Nairobi. The annual numbers of mammography examination were counted from the hospital patient records. The hospital radiology department operates LORAD M-IV unit manufactured by Hologic, Inc. Lorad (Danbury, U.S.A). The equipment has manual and AEC systems, Mo/Mo and Mo/Rh target combinations, two focal spots of 0.3 and 0.1 mm. The unit is regularly tested during routine quality control (QC) checks. Dedicated image viewing boxes and film processing unit are used; the latter is an automatic processor (Kodak MIN-R 2000). The mammography x-ray unit is adjusted for target optical density of 1.4-1.8 with the same type of film-screen system (AGFA Mamoray HDR-C). The unit has an inherent filtration of 0.34 mm of aluminium (Al) and accepts both 18×24 cm^2 and 30×24 cm^2 format films with grid.

The examinations were performed by more than one imaging technologist with adequate experience in mammography imaging techniques. Age, CBT for each projection, tube voltage (kV), target/filter combination, tube loading (mAs), optical density settings and angle of MLO projections were recorded for each patient. Adult female patients between the ages of 25 to 90 years with a clinical prescription request were included. The automated measurement of CBT was verified using a ruler at a distance of 4 cm from the chest wall (4).

Average glandular dose (AGD) values are obtained using equation 1

$$AGD = D_{gN}\ X_a \qquad (1)$$

where D_{gN} is the average glandular dose (mrad) resulting from incident exposure in air of 1 R, (5) and X_a is the incident exposure in air needed to produce a proper image density measured by the equipment inbuilt dosimeter. AGD per woman was calculated by summing the AGDs for all films and averaging it over the two breasts (6).

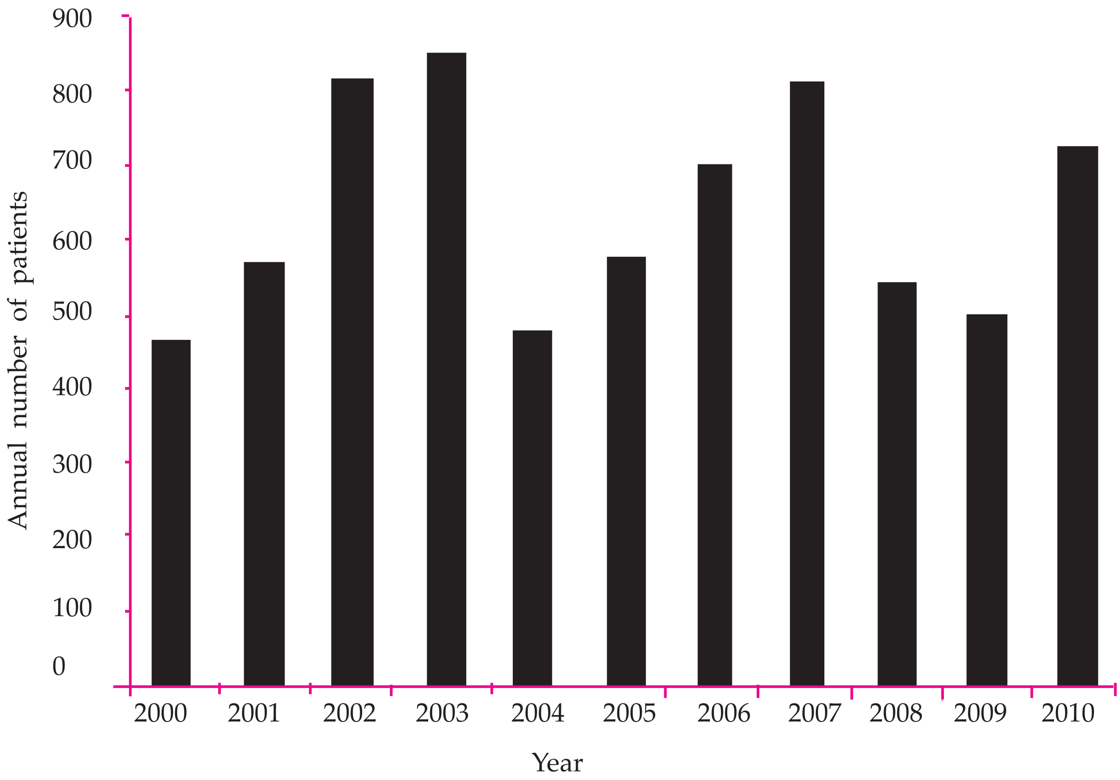
Inspection of the mammography unit was done to ensure that all locks, dents, angulation indicators, and mechanical support devices for the x-ray tube and image receptor holder assembly were operating optimally. The mammography equipment was subjected to performance test based on the quality control parameters indicated in Table 2 using calibrated Unfors Instrument AB equipment (Billdal, Sweden). The tests results were evaluated for compliance according to the specifications of the New South Wales Environment Protection Authority Methods and Standards (7). The view box luminance and room illuminance were assessed using the luminance and illuminance meter model L991260 (Canberra, Schwadorf).

Each mammogram obtained from each examination and measurements recorded were assessed for image quality compliance by experienced Radiologists according to European Commission (EC) quality criteria (8). A grading system of A, B or C was assigned for each radiograph. Grade A meant accepted unconditionally (visually sharp reproduction of the whole glandular breast, the cutis and the subcutis and nipple parallel to the film), B meant accepted with reservations (features just visible, details just visible but not clearly defined) and C meant rejected radiograph (features invisible, details invisible and undefined.)

RESULTS

Figure 1 indicates the number of mammography examinations in the past decade. During the same period 10% of mammogram examinations were ductograms. This study estimates the hospital annual number of mammography examinations to be 650 with a monthly average of 70 patients.

Figure 1
Annual number of Mammography examinations



The operating condition of the mammography units is summarised in Table 1. This is considered as a typical representation of the general operating conditions of the equipment.

Table 1
Typical characteristics and radiographic parameters for the LORAD M-IV mammography unit

1. Focus to Film Distance(cm)	70
2. Anode Material(s)	Mo and Rh
3. Filtration (μm material)	Mo (30μm) and Rh (25μm)
4. Exposure Techniques(kV:mAs)	Mo:Mo (kVp 26-28:mAs 110-137)
5. Tube Voltage	22-39kV
6. Output (μGy/mAs)	241
7. HVL (mm Al)	0.34mmAI (at25kVp)
8. Standard breast AGD (mGy)	1.42
9. Grid ratio	3:5:1
10. Mode of Operation	AEC
11. Measured display breast thickness accuracy (cm)	5 ± 0.3
12. Film processor	Min-R
13. Processing temperature (^{0}C)	35
14. Processing time (sec)	120
15. Screens	Rare Earth
16. Films	Agfa/Kodak

Table 2
Mammography equipment performance tests results

Quality Control Test		Results	Comments (Pass/Fail)
1. Mammography unit assembly evaluation			
	Free-standing unit is mechanically stable.	Yes	Pass
	All moving parts move smoothly, without obstructions to motion.	Yes	Pass
	All locks and detents work properly.	Yes	Pass
	Image receptor holder assembly is free from vibrations.	Yes	Pass
	Image receptor is held securely by assembly in any orientation.	Yes	Pass
	Image receptor slides smoothly into holder assembly.	Yes	Pass
	Compressed breast thickness scale is accurate to ±0.5 cm, reproducible to ±2 mm.	Yes	Pass
	Patient or operator is not exposed to sharp or rough edges or other hazards.	Yes	Pass
	Operator technique control charts are posted.	Yes	Pass
	Operator protected during exposure by adequate radiation shielding.	Yes	Pass
	Indicator lights working properly.	Yes	Pass
	Auto-decompression can be overridden to maintain compression (status displayed).	Yes	Pass
	Manual emergency compression release can be activated in event of power failure.	Yes	Pass
2. Collimation assessment x-ray field and light field on any edge (< 1% of SID)	Left edge deviation (mm)	-1.0	Pass
	Deviation as % of SID	-0.1	Pass
	Right edge deviation (mm)	1.5	Pass
	Deviation as % of SID	0.2	Pass
	Nipple edge deviation (mm)	2.5	Pass
	Deviation as % of SID	0.4	Pass
	Chest wall edge deviation (mm)	-2.0	Pass
	Deviation as % of SID	-0.3	Pass
X-ray field extension on image receptor edges (< 2% of SID)	Left edge deviation (mm)	0.0	Pass
	% of SID	0.0	Pass
	Right edge deviation (mm)	5.0	Pass
	% of SID	0.7	Pass
	Anterior edge deviation (mm)	5.0	Pass
	% of SID	0.7	Pass
	Chest edge deviation (mm)	1.0	Pass
	% of SID	0.1	Pass
Chest wall edge of compression paddle extension on image receptor (< 1% of SID)	Diff. paddle edge & film (mm)	0.0	Pass
	Diff. as % of SID (mm)	0.0	Pass

3. Nominal kVp accuracy (± 5%)	5.0	Pass
4. kVp Reproducibility (coefficient of variation ≤ 0.02)	0.02	Pass
5. Half Value Layer-25kVp Mo/Mo (0.28-0.37 mm Al)	0.34	Pass
6. Radiation Output Rate 25kVp Mo/Mo (< 7 mGy/s for large focus)	5.0	Pass
7. Automatic exposure control system (1.43-1.83 Optical Density range)	1.63	Pass
8. Average Glandular Dose-25 kVp Auto mAs (> 2mGy (200 mrad) for a 50% glandular, 50% adipose, 5.1 cm, effective breast thickness)	2.12	Pass
9. View box Luminance (≥3,000 cd/m2)	2500	Fail
10. Room Illuminance (<50 lux)	65	Fail

The distribution of tube voltages and tube loading in the study sample are indicated in Figures 1 and 2 respectively. Majority of CC and MLO views were performed using 25 kVp with a mean range of 24-25 kVp using molybdenum target/filter. The mean mAs values were 125 and 136 for the CC and MLO views respectively.

Figure 2
Distribution of tube voltages used in mammography

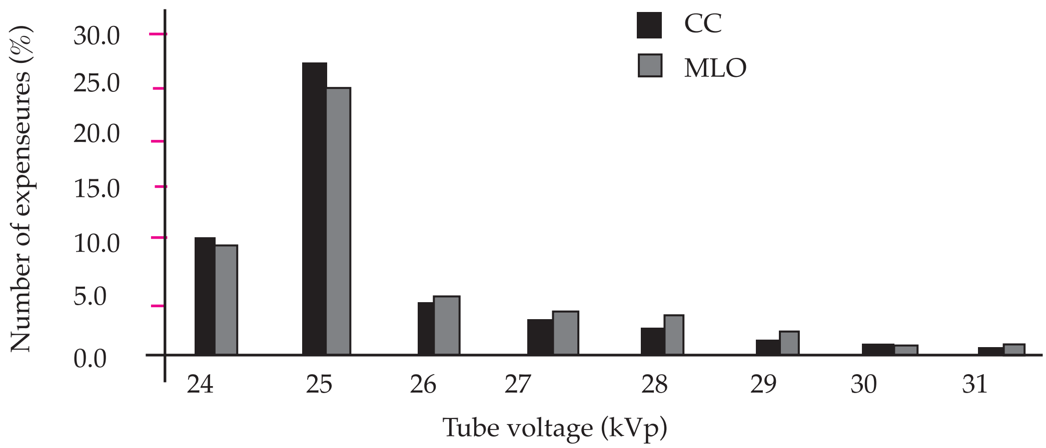


Figure 3
Distribution of tube loading used in mammography

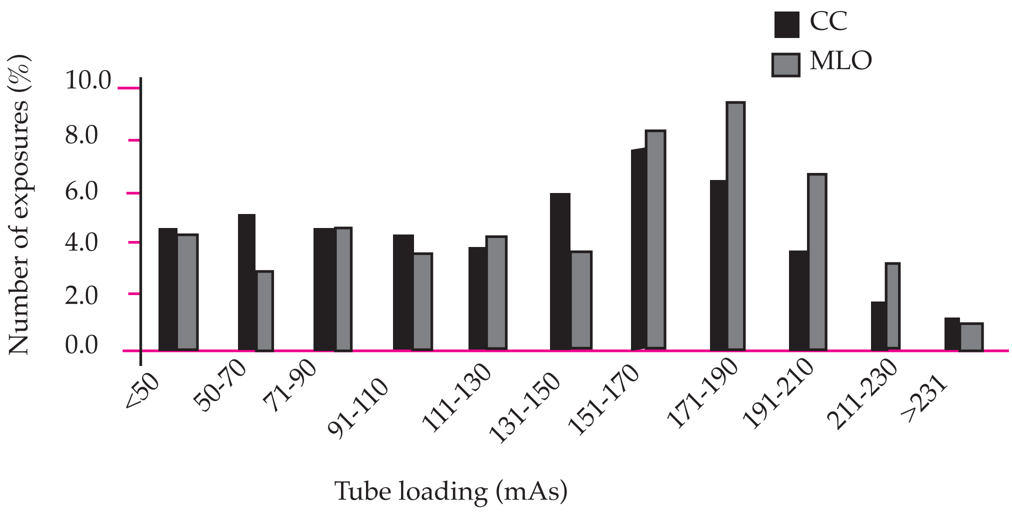


Figure 4 indicate the mean age for the study sample as 49 years (range 25–90 years) and close to the age of menopause (median age is 51 years in the UK), during which significant changes in composition of the breast are known to occur (10). The results in this study were in agreement with the Society of Breast Imaging and the American College of Radiology which recommends relatives of mothers or sisters with pre menopausal breast cancer to start breast cancer screening by age of 30 years but not before age 25 or 10 years earlier than the age of diagnosis of the youngest affected relative (11). In this study 68% of breast examinations were between 30 to 49 years old. This indicates that incidences of breast cancer affecting a younger age group are on the rise. The findings correlate with the young Kenyan population and the need for optimal radiation protection in mammography. The high percentage of MLO for the 50-54 age brackets was associated with diagnostic and screening activities.

Figure 4

Age distribution of the cranio-caudal (CC) and medio-lateral oblique (MLO) views in the study sample

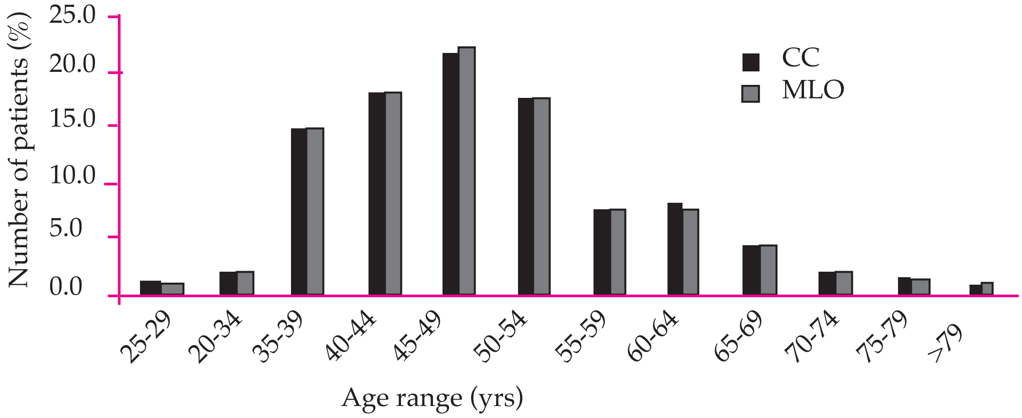
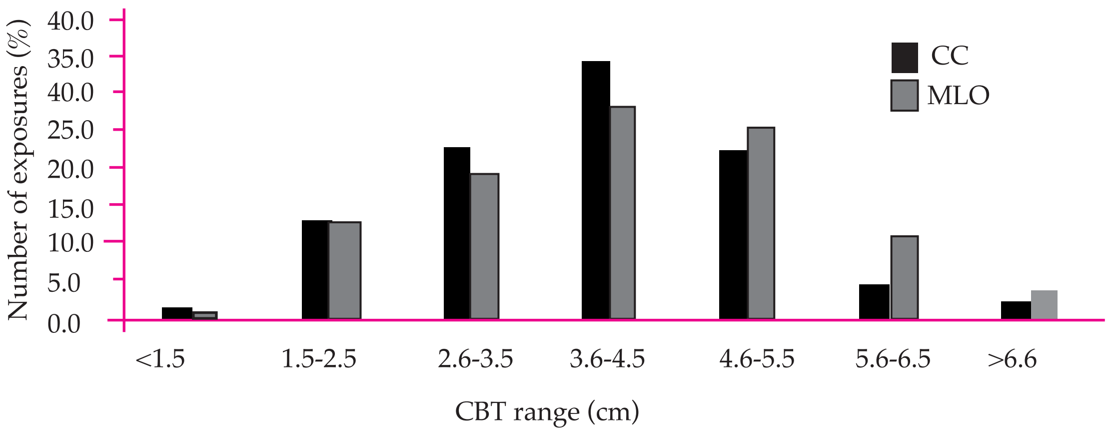


Figure 5 indicates the CBT range, which is distributed symmetrically between 1.5 centimetres to 6.6 centimetres, for both CC and MLO views. The mean CBT value was 4.0 centimetres for both the CC and MLO views, with a standard deviation of 1.3 centimetres.

Figure 5

Histogram showing the percentage of films as a function of compressed breast thickness for cranio-caudal (CC) and medio-lateral oblique (MLO) views



A histogram showing the percentage of the number of films as a function of the AGD per film for CC and MLO views is shown in Figure 6. An increase in AGD with respect to increasing CBT reached a maximum of 9.43 mGy for CC and 10.12 mGy for MLO views.

Figure 7 indicates the distribution of the AGD per woman for which the average was 4.52 mGy. Figure 8 indicates the percentage distribution of image quality grading scores at the Radiologists' level.

Figure 6

Distribution of the percentage number of films as a function of average Glandular Dose (AGD) per film for cranio-caudal (CC) and medio-lateral oblique (MLO) views

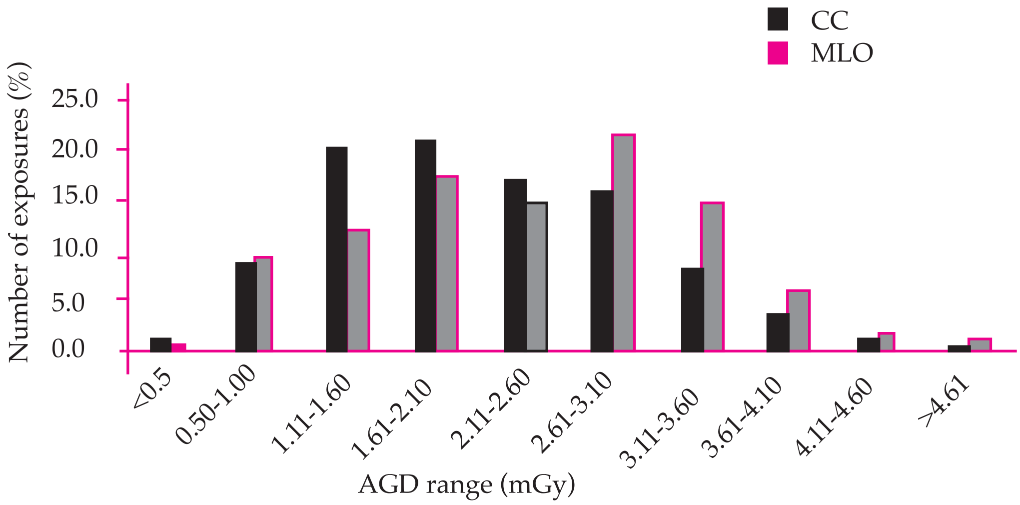


Figure 7

Distribution of average Glandular Dose (AGD) per women in the study sample.

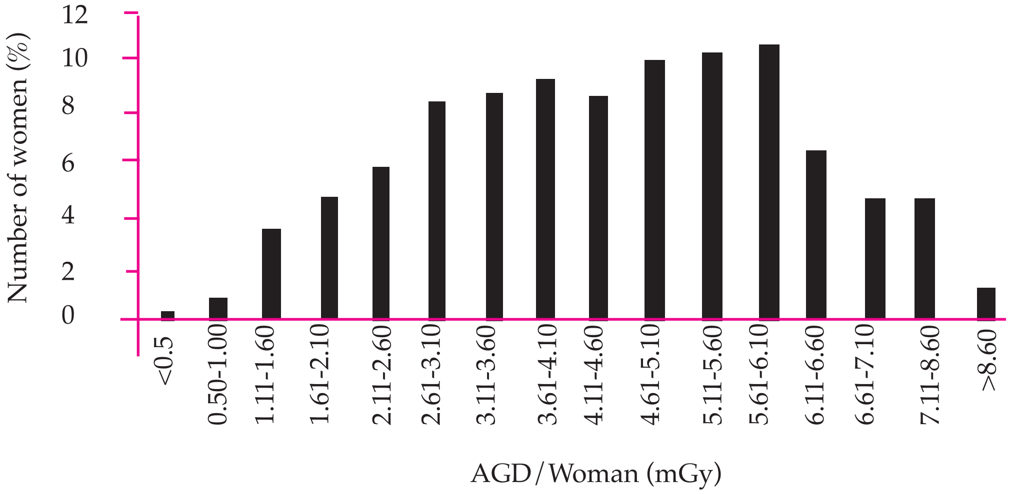
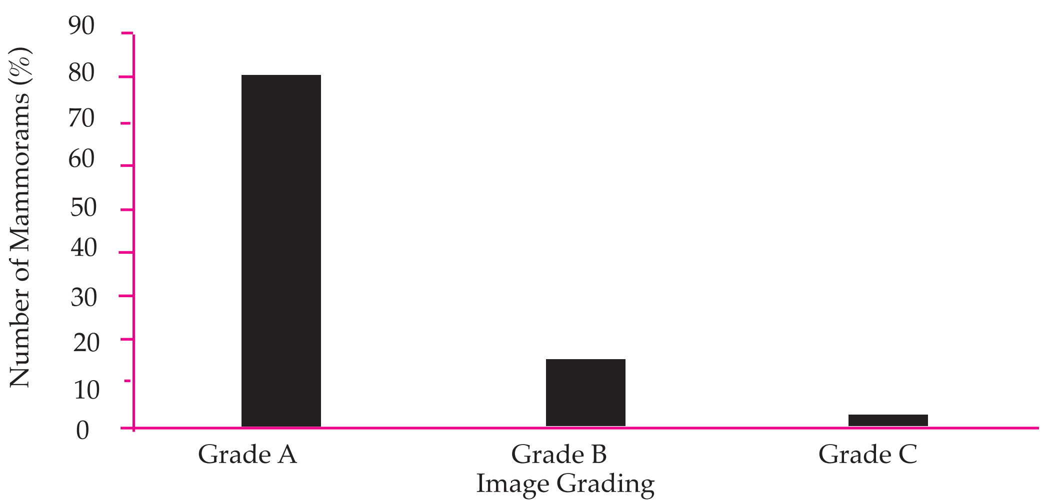


Figure 8

The image quality assessment results



DISCUSSION

The number of mammography examinations increased by 45% in four years from 2000 and by 41% in the next four years from 2004 to 2007. The decrease in the number of mammography examinations in 2008 and 2009 is attributed to the installation of new mammography facilities across the country, increase in breast ultrasound and MRI scan examination for those less than 30 years old and justification scrutiny of the request forms by Radiologists. The enhanced sensitisation of self breast examination awareness and mammography screening resulted in the increase of mammography facilities and examinations across the country.

The quality control tests listed in Table 2 were performed to ensure continued appropriate levels of equipment performance during the study. These tests were also designed to be done by the medical physicist at least once a year. The physicist's tests focused on the mammography system tests of parameters expected to change slowly. It is worthwhile to note that the distinction between the technologist and physicist QC tests is largely in the period over which the parameter is expected to vary significantly. The Technologist's frequent quality control tests done were indicators of early warning of impending equipment malfunction or Engineer/Physicist required attention. All the quality control tests performed were passed except luminance and ambient light. The viewing boxes are less bright while ambient light in the reporting room is too bright to the extent that it may affect the level of viewing diagnostic information in the mammograms.

Optimal mammography practice is dependent on a well established quality assurance program that includes assessment of patient dose. At International level, inter comparisons between different mammography facilities using standard breast phantom protocol are established (12-15). The limitation of this method is the failure to address actual patient dose which may vary due to patient age, breast composition and size. The patient based method used in this study contributes towards understanding the patient breast glandular texture and dose in mammography. The results from this study can be used by equipment manufacturers in developing tailor made protocols suitable for mammography practice in Africa.

The average Glandular Dose (AGD) per film for CC and MLO views showed respective figures of 83% and 71% below the 3 mGy diagnostic reference dose, for a single cranio-caudal projection of standard breast. From this study, the local diagnostic reference levels derived from the patient based survey and images of diagnostic value are 2.77 mGy and 3.09 mGy for CC and MLO views respectively. The AGD per film for the MLO (2.44 mGy) was higher by 12% when compared with the CC view (2.14 mGy). The increased dose was associated with the CBT observed for MLO where the views were performed with 27% higher compression force as compared to force used for the CC views. This was also attributed to the inclusion of the denser pectoral muscle in the image of MLO projection as revealed in the increased CBT in Figure 5. A careful assessment of image quality and use of a 60^0 angle when projecting MLO views could reduce the AGD dose (16). However, some studies have shown reduction of the AGD observed for small and large MLO projection angles than the common 40^0 or 45^0 angles (17). The 4.52 mGy AGD per woman was not correlated with patient age but was higher than the reported values in the literature (19). This is attributed to the study sample breast density and the clinical indication of mammography.

The high image quality scores in this study were due to the skilled technologist and regular quality control tests performance. Grade C rejects were mainly due to inadequate compression with poor contrast and loss of glandular detail. The scientific and technical skills on equipment performance and the imaging technologist's skill are essential in mammography practice. Image quality and patient doses in mammography depend heavily on target/filter, source to image distance, beam energy, grid, optical density, film speed and processing, compressed breast thickness and composition.

In conclusion, the Kenyan population is relatively young and constitutes a larger female percentage and hence this baseline data is essential in instituting quality assurance programs before the introduction of mammography screening program in the country. Local diagnostic reference levels (LDRLs) were proposed to facilitate optimisation without compromising image quality, strengthen quality assurance and contribute towards developing the national diagnostic reference levels. The results revealed the need for integrated quality assurance programs and routine clinical patient dose assessment in mammography practice. These are the first ever presented mammography dose assessment data in Kenya. Although valuable information on equipment and techniques have been established for optimisation strategies in mammography at the national referral hospital, there is also a need to extend the survey to include all mammography facilities across the country.

ACKNOWLEDGEMENTS

We sincerely thank the Ministry of Health, Management and Radiology staff of Kenyatta National Hospital for accepting to participate in the IAEA projects (RAF/9/033- *Strengthening Radiological*

Protection of Patient and Medical Exposure Control and coordinated Research project Contract No. 16988: Enhancing Capacity for Early Detection of Breast Cancer through Imaging"), the National Council for Science and Technology and the International Atomic Energy Agency for their support.

REFERENCES

1. Kenya National Bureau of Statistics. Kenya 2009 Population and Housing Census Highlights, The Regal Press Kenya Limited, Nairobi. 2010.
2. Kenya Medical Research Institute. Cancer Incidence Report Nairobi 2000-2002. Nairobi: Nairobi Cancer Registry, 2006.
3. International Commission on Radiological Protection. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Annals of the ICRP 37 (2-4). Oxford: Pergamon Press, 2007.
4. Highnam, R. P., Brady, J. M. and Shepstone, B. J. Estimation of compressed breast thickness during mammography. *Br. J. Radiol*. 1998; **71**: 646–653.
5. National Council on Radiation Protection. National Council on Radiation Protection and Measurements. Mammography, A User's Guide. Bethesda, MD. NCRP Report No. 85. Bethesda, MD: NCRP, 1986.
6. Young, K.C. and Burch, A., Radiation dose received in the UK Breast Screening Programme in 1997 and 1998. *Br. J. Radiol* 2000; **73**: 278–287.
7. Environment Protection Authority (EPA). Registration requirements and industry best practice for ionizing radiation apparatus used in diagnostic imaging. Radiation Guidelines; Test protocols for part 1 Mammography. Sydney: New South Wales: EPA, 2004.
8. European Commission. European guidelines on quality criteria for diagnostic radiographic images, EUR 16260 EN. Brussels: CEC, 1996.
9. American College of Radiology (ACR). Mammography quality control manual. Washington, DC: ACR. 1999.
10. Beckett, J. R. and Kotre, C. J. Dosimetric implications of age related glandular changes in screening mammography. *Phys. Med. Biol*. 2000; **45**: 801–813.
11. Lee, C. H., Dershaw, D., Kopans, D. Breast Cancer Screening with Imaging: Recommendations from the Society of Breat Imaging and the ACR on the use of Mammography, Breast MRI, Breat Ultrasoung, and other Technologies for the detection of Clinicall Occult Breast Cancer. *JACR* 2010; **7**: 1546-1440.
12. Australasian College of Physical & Engineers in Medicine. A Quality Assurance in Mammography Screening. *Australas. Phys. Eng. Med*. 1989; **12**: 252-259.
13. Institute of Physical Sciences in Medicine (IPSM). The Commissioning and Routine Testing of Mammographic X-ray systems. Topic Group Report 59 York: IPSM 1989.
14. American College of Radiology (ACR) Committee on Quality Assurance in Mammography. Mammography Quality Control: Medical Physicists Manual. Reston, VA: ACR, 1999.
15. European Commission. European guidelines on quality assurance in mammography screening, EUR 14821. Brussels: CEC, 1993.
16. Brnic, Z. and Hebrang, A. Breast compression and radiation dose in two different mammographic oblique projections: 45 and 60 degrees. *Eur. J. Radiol*. 2001; **40**: 10–15.
17. Tsapaki, V., Tsalafoutas, A., Poga, A., *et al*. Investigation of breast dose in five screening mammography centres in Greece. *J. Radiol. Prot*. 2008; **28**: 337–346.
18. Jamal, N., NG, K. H. McLEAN, D. A study of mean glandular dose during diagnostic mammography in Malaysia and some of the factors affecting it. *Br. J. Radiol.* 2003; **76**: 238–245.