Sudan University of science and technology

College of Gradated studies

Evaluation of image quality in digital mammography in Khartoum state

تقييم جودة الصورة لجهاز تصوير الثدي الشعاعي الرقمي في بعض مستشفيات ولاية الخرطوم

A thesis submitted to Sudan A thesis submitted to Sudan Academy of Sciences in partial fulfillment of The requirements for the degree of M..Sc. in Medical Physics

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2019

Dedication:

To

My Parents

And

My Teachers

Acknowledgements

Thanks for my supervisor. Dr. Hussin and Sudan Academy of sciences and Atomic Energy Councildue to help me.

Abstracts:

The mammography is examination of x – ray to early detection of the breast cancer. However the delectability of micro calcifications is required high quality image. Thus evaluation of image quality is important.

The main objective of this study was to evaluate image quality for full field digital mammography at omer sawey hospital Khartoum state - Sudan.

The tests that were performed in this study include: Contrast to noise ratio and spatial resolution. Contrast to noise ratio was evaluated by acquiring images for different thickness (20, 40, 60, 70 mm) of PMMA phantom and aluminum sheets 0.2mm thickness (as contrast object) and analysis image by image J software. Spatial resolution was evaluated by acquiring image for (3.5mm) of PMMA phantom and bar pattern as lp/mm.

Result of this study: the contrast to noise ratio for 9 20, 40, 60, 70 mm) was (213,211,200, 184.8) respectively and spatial resolution for (3.5mm) was (18lp/mm).

Conclusion: contrast to noise ration and spatial resolution was found within acceptable value according to European protocol.

المستخلص

تصوير الثدي بألاشعة السينية هو فحص للكشف المبكر لسرطان الثدي. وفي تصوير الثدي نبحث عن نسيج دقيق وبالتالي يتطلب صورة ذات جودة عالية.

الهدف الاساسي من هذا البحث هو تقييم جودة الصورة لجهاز تصوير الثدي الرقمي في مستشفى عمر ساوي ولاية الخرطوم - السودان .

الاختبارات التي أجريت في هذه الدراسة هي نسبة التباين الي الضؤضاء وذلك بأخذ اربعة صور لفانتوم PMMA في كل صورة بسمك مختلف(20, 40, 60, 70 مم) وشريحة من ألأمونيوم سمكها 0.2مم وتم تحليل الصور برنامج image J وكذلك تم قياس التمييز بين نقطتين بأخذ صورة (3,5PMMAمم) وتم التقييم بطريقة lp/mm.

وكانت النتائج بالنسبة للنسبة بين التباين والضوضاء لاربع صور ذات سمك مختلف (20,40,60,70مم) هي (213,211,200,184,8) وبالنسبة للتمييز بين نقطتين كانت(3,5مم) هي(lp/mm18). خلص هذا البحث الي ان النتائج مقبولة وفقا للبروتوكول الأوربي.

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List of Abbreviation:

FFDM	Full Field Digital Mammography
AEC	Automatic Exposure Control
PMMA	Poly Methyl Metharcylate
mAs	milliambere . Second (tube current. time)
kVp	kilo – volt peak
HVL	Half Value Layer
MGD	Mean Glandular Dose
mGy	milli Gray

Chapter One

Introduction

Chapter one

Introduction

1.1 introduction:

Screening mammography invites healthy women for an x – ray examination of breast, with the aim of early detection of breast cancer. The benefits of the screening mammography have been scientifically examined and it has been shown, on the basis of randomized controlled trails, that screening mammography reduces breast cancer mortality by up to 25. The international Agency for which they concluded that mammography screening is still effective in reducing breast cancer mortality (Moyyad etal,2017). Mammography efficacy in detecting breast cancer in early stages comes with a small but non negligible risk of radiation induced cancer to the fibro glandular tissues of the breast and possibly other exposed organs. In the mammography examination we detect subtle features such as low contrast small area mass lesions, micro calcifications and architectural distortions. Additionally, the background morphology of the breast can vary from low contrast uniform areas to very high contrast busy area and breast tissue is one of the sensitive tissues to radiation, therefore mammography equipment needed to high quality assurance program(Work MAN,etal,1994).

In this study we evaluation of image quality for one digital mammography system base on European protocol Image quality we assess spatial resolution, , spatial resolution is the ability of an imaging system to allow two adjacent structures to be visualized as being separate, or the distinctness of an edge of the image (i.e. sharpness) and describes star or bar pattern. Also we assess contrast to – noise ratio which is good indicator delectability using polymethylmetharcylate (PMMA) with different thickness 20,40, 60 and 70mm and aluminum sheets with 0.2mm.

1. 2 problem of study

The digital mammography necessitates regular quality control and less concern from concerned party. In addition, all department, even in big hospitals, have no quality control tools or quality assurance program and because tissue breast very small, very low different attenuation coefficient between tissue .therefore, it is required very accuracy of qc.

1. 3Objectives:

1. 3 .1 General objectives:

To evaluate image quality of digital detector for full field digital mammography in Khartoum state.

1. 3. 2 Specific objectives:

- Quality control
- Calculate contrast to noise ratio.
- Measure spatial resolution..

1. 4 Thesis of the study:

The thesis falls into five chapters; chapter one consist of idea of mammography, problem of study, objectives of study. Chapter two consist theoretical background, digital mammography device and characteristics of it, quantities and units, while chapter three discusses the materials and methods, in chapter four presentations of the result and discussion, finally chapter five consists conclusion and recommendations.

Chapter Two

Literature Review

2. Theoretical back ground

2.1 Components of Digital mammography:

A mammography machine has two major components that make it more effective for breast screening than any other radiographic machines. These two components are, type of x-ray tube i.e. target/filter combination and compression paddle.

2.1.2 X -ray tube:

The mammography x- ray tube is typically formation from two filaments in focusing that produce o.3 and o.9 mm nominal focal spot sizes. A small focal spot minimizes geometric blurring and enhance spatial resolution which is necessary for micro calcification detection. A important difference in mammographic tube operation compared to conventional radiographic operating is low operating, from 20 to 40 kvp . The space charge effect causes a nonlinear relationship between the filament current and tube current. Feedback circuits adjust the filament current as function of kv to deliver the desired tube current(Jerroldet al., 2002)**.**

2.1.3 A node:

Mammographic X-ray tubes use a rotating anode design. Molybdenum is the most common anode material, although rhodium and tungsten targets are also used. Characteristic X-ray production is the major reason for choosing molybdenum and rhodium. For molybdenum, characteristic radiation occurs at 17.5 and 19.6 keV and for rhodium, 20.2 and 22.7 keV. As with conventional tubes, the anode disk is mounted on molybdenum stem attached to a bearing mounted rotor and external stator, and rotation is accomplished by magnetic induction. A source to image distance (SID) of 65 . X- ray tube anode angle vary from 16 to 0 degrees to -9 degrees. The latter

two anode angles are employed on a tube with focal spots on the edge the anode disk. The effective node angle in a mammographic x- ray tube is defined as the angle of the anode relative to the horizontal tube mount. Thus for a tube with 0 a degree and 9- degree and anode angle, a tube angled of 24

degrees results in an effective anode angle of 24 degrees for the large (0.3 mm) focal spot , and 15 degrees for the small(0.1 mm focal spot).

In other mammography x- ray tubes, the typical anode angle is about 16 degrees, so the tube is oblique by about 6 degrees to achieve an effective anodeangle of 22 degrees. A small anode angle allows increased mill amperage without overheating the tube, because the actual focal spot size is much larger than the projected focal spot. The lower x- ray intensity on the anode side of the field (heel effect) at short SID is very distinguished the mammography image.

Positioning the cathode over the chest wall of the patient and the anode over the nipple of the breast achieves better uniformity of the transmitted x- ray through the breast.

Positioning the cathode over the chest wall of the patient and the anode over the nipple of the breast achieves better uniformity of the transmitted X-rays through the breast. Orientation of the tube in this way also decreases the equipment bulk near the patient head for easier positioning. Mammography tube often has grounded anodes, where by the anode structure is maintained at ground (0) voltage and the cathode is set to highest negative voltage. With the anode at the same voltage as metal insert in this design, off focus radiation is reduced because the metal housing attracts many of the rebounding electrons that would otherwise be accelerated back to the anode(Jerrold ,T,et al, 2002).

2.1.4 Filter:

Filter use to reduce unnecessary exposure to the patient, mammography uses filter that work on different principle and are use to enhance contrast sensitivity. Filters uses in mammography are molybdenum (Mo), ruthenium (Ru), rhodium (Rh), palladium (Pd), silver (Ag), and cadmium (Cd). Molybdenum (same as in the anode) is the standard filter material(Jerrold et al., 2002).

2.1.5 Compression paddle:

Compression uses in mammography for several reasons, minimizing superposing from different planes and therapy improving the conspicuity of the structures, resulting in the various tissue being spread out by different amounts and potentially making a cancer easier to see. And also the compression decrease the ratio of the scattered radiation reaching the detector and enhance the contrast image, compression also decreases the distance from any plane within the breast to image receptor, and in this way reduces geometric un sharpness. The compressed breast provides lower overall attenuation to incident x –ray beam, allowing radiation dose reduced. The compressed breast also provides more uniform attenuation over the image.

This reduces exposure range. Finally, compression breast provides a Clamping action, which reduces anatomical motion during exposure, thereby reducing this Source of image un- sharpness. It is important that the breast must be compressed as uniformly as possible and that the edge of the compression plate at the chest wall be straight and aligned with the focal spot and image receptor to maximize the amount of breast tissue that is included in the image (Jerrold et al., 2002).

Figure 1: FFDM with its workstation

As Digital mammography is equipment use to imaging breast to detect early cancer. There are two main types of digital mammography imaging systems. One type uses full field detector to be imaged, the detector in these system stationary and system may utilize a grid to remove x-ray scatter, thereby increasing Signal –to- noise ratio. The second major type of digital mammography system is a scanning-slot device that uses a detector rectangular in shape(Cherieet al.,2012).

2.1.6Detector system

The detector is one of the key components of digital mammography system .it has several functions one is absorption, interaction and converts x ray transmitted from breast into electronic signal other function collection of this signal,

readout of the charge, amplification, and finally digitization of the information .optimally, a detector should include the entire range of x –ray intensities transmitted by different areas of the breast without of information.to provide high quality images , all of these steps need to be optimized .as result , detectors are characterized by their quantum efficiency, sensitivity, spatial resolution ,noise, dynamic range and linearity of response (Cherie et al. , 2012).

2.1.7 Selenium flat panel

A selenium detector utilizes a thin layer of amorphous selenium for a- ray absorption. X- Ray incident on the amorphous selenium absorbed by it , and causes some electrons in the selenium to be liberated .this electrons became free and its corresponding "hole" from its departure create an electron-hole pair. This electron –hole creates the signal. When electrodes are placed above and below the selenium and applied this causes the charges to move toward the electrodes. The signal is collected by one of the electrodes that are composed of a large matrix of dels. The dels acts as capacitors to store the charge. At the corner of each del is a TFT switch .in the Fuji system, detector contain on two layers, the upper layer of selenium absorbs the x-rays and produces the electron-hole pairs. The charge is then stored in each del. the lower selenium layer will transfer the stored charge to a set of readout of lines and then it will be transferred to an amplifier and digitized. The information from one del will be used to create the information corresponding to pixel of the image. This system has a bit depth of 14.other type of other detectors: Phosphor flat panel-phosphor-CCD system-photostimulable phosphor system x-ray (photon) quantum counting (Cherie et al., 2012).

2.1.8 Image acquisition

In digital mammography, a detector replaces the screen film system. When detector exposed to radiation it produce signal that is linear proportional to the intensity of the photons transmitted by the breast; therefore, it is possible to produce a better representation of the x-ray transmission of all parts of breast. AEC in digital mammography aids in obtaining a predetermined signal –to-noise ratio and a reasonable radiation dose to the breast. After being exposed, the digital detector produces an electronic signal that is digitized and stored. wet chemical processing in digital mammography is eliminated and detectors only role is image acquisition. Another benefit of the detector is the elimination of film granularity that adds noise to system (Cherie et al. , 2012).

2.1.9Image display system

Image display of digital images can be performed with a laser printer onto hard copy "film like" medium or viewed on high-resolution computer monitors. Regardless of display type, it is important to known how the image is been seen relative to its full spatial resolution. Commercial laser printers for digital mammography can support spatial resolutions, grey scale and optical density similar to mammography film. If the images are printed with a laser printer, it may be done with 8, 10, or 12 bits per pixel displayed if a digital mammography system uses larger bits than the printer, there will be less of the dynamic range of digital image and contrast scale will be compressed. an advantage of laser –printed film is that it allows radiologist to use same reading and workflow protocols as SFM. soft copy display is performed with high resolution mammography monitors that allow the flexibility of image display and contrast.

For radiologists using softcopy display for copy display is performed with high resolution mammography monitors that allow the flexibility of image display and contrast. For

radiologists using softcopy display for interpretations, appropriate room ergonomics and viewing conditions are absolutely necessary to minimize radiologist distractions and fatigue. 8Vendors need to continue developing hanging protocols and other tools that allow the radiologists to view all digital images with little manipulation of buttons or clicks of the mouse (Cherie et al., 2012).

2.1.10Radiation dose:

Radiation dose in digital mammography is lower than in screen film mammography. Several factors account for this decreased dose First , image brightness (display) in digital mammography is not dependent on the amount of x- ray exposure needed to produce the image , it allows the use to determine the dose selection. Secondly, digital detectors have higher detective quantum efficiency with decreased signal- to- noise ratio than SF image receptor. Consequently, a more penetrating x-ray beam can be used with digital mammography, and this result in a lower patient dose. Currently, some digital mammography systems have dose reductions of 25-30% compared with SFM (Cherie et al.,2002).

2.1.11 Image Retrieval

Digital mammograms are very large and, in many cases, may have to be downloaded from a central As dig PACS archive to a specialized high resolution workstation for review, it is essential that communication bandwidth be sufficient to avoid bottlenecks. Note that for image element sizes of 50mm and 100mm, transmission of a4 -view examination at

standard modem rates (56kb/s) would require about 7 hours and 1.8 hours respectively. With full 100MB/S bandwidth, these times reduced to 14.4 and 3.8 seconds, although, in practice, bandwidth generally must be shared with other applications. As mammography examinations during low demand periods, such as at night, so that they are readily available when required for comparison. Images are often sent to PACS system, as well as the diagnostic work station used for that modality, so that they will be available for immediate viewing. Data compression can significantly reduce the size of images. A PACS system should be able to store and expand images provided in compression formats meeting DICOM specifications. Primarily for medico – legal reasons loss compression is not currently considered for mammographic imaging. Despite the claims of compliance with the DICOM standard made by the manufacturers of various digital mammography units and PACS systems, it is still quite common to encounter compatibility problems when storing DICOM images to and retrieving them from PACS systems. This is particularly true when using technology from different vendors.

The person(s) responsible for integrating the systems must carefully read the DICOM conformance statements of the of the different components they should also be prepared to spend considerable time and effort working with the vendor to ensure that images can be satisfactorily stored and retrieved(Yaffe MJ,.2004)

2.1.12 A advantages of digital mammography:

Digital mammography offers several advantages over SEF. The digital mammography system separates the process of the x-ray detection from image display and storage. Since image acquisition and display are separated, each can be optimized;

Digital detectors have wider dynamic range compared to film. Digital detectors have increased efficiency at lower radiation dose in detection and depiction of the x-ray photons compared to film (pisano, 1998; feig, 1996). In addition , digital detectors (even with a lower spatial resolution than film) also appear to improve lesion conspicuity through their improved efficiency of absorption of x- ray photons, a linear response over wide range of radiation intensity and low system noise (Feig&Yaffe, 1998). Improved accuracy of diagnosis in the dense breast Higher throughput of image acquisition; elimination of problems associated with chemical processing (i.e. environmental and occupational health issues,

and costs related to film and processing chemistry); Improved archival and retrieval capabilities; The possibility of introducing new techniques (computer assisted detection (CAD), telemammography, tomosynthesis, contrast enhanced digital mammography); The ease of providing images to be used as teaching tools (International…2o11).

2.1.13 Disadvantages of digital mammography:

Higher capital costs, to adjust to new technology, Possible to increase radiation dose (it should be noted that depending on the system design, the choice of technique factors and attention to QC, doses in digital mammography can be either lower or higher than those in screen film mammography ,Incompatibility between different digital systems, Difficulty in providing images to non digital facilities (e.g. referring physicians, More demanding environmental requirements (e.g. properly conditioned electrical power, dust control and lighting conditions, internet connections, ventilation and air conditioning). For example, many digital units require air conditioning to be provided 24 hours, 7 days a week to prevent damage to detector (International…2o11).

2.3Literature Review:

Study on patient dosimetry and image quality in digital mammography

Carvalho da SILVA Xavier et al. the study carried out in four clinics (two DR, one CR and one SF) located in cities of Recife, northeast region of Brazil. MGD estimated for images 5475 patients with age between 40 64 years, with compressed breast between 2 and 9 cm , and the image quality evaluated based on the quality Assurance programme for digital mammography (international…, 2011). Their concluded that the use of non optimized irradiation parameters is causing the higher dose with the digital system, highlighting the insufficient compression force.

Evaluation of doses and image quality in mammography with screen – film,CR and DR, AND detectors - application of the ACR phantom in MazoviaVoivodeship, poland

Slusarzyk – Kacprzyk et al. Evaluated doses and image quality in 26 SF system, 12 CR systems, and 9 DR systems. The MGD for breast simulated by 4.5 cm of PMMA calculated with methods described in the" European guideline for quality assurance in breast cancer screening and diagnosis". Visibility of structures in image was evaluated with the mammographic accreditation ACR phantom. And their found the best image quality, at reasonably low dose, was observed for DR systems. The doses for CR systems were significantly higher than for SF and DR systems.

Determination of dose delivery accuracy and image quality in full field digital mammography in Accra, Chana.

Sosu et al. determined the MGD and image quality in full field digital mammography in Accra, Chana. The study carried out assessing Fujifilm – Amuleft full field digital mammography equipment with source image distance 65 cm, target filter combination of Tungsten – Rhodium, KVp range 23 -35kvp and mAs range 2 -600 .

Chapter Three

Material and Method

Chapter Three

Materials and methods

3.1 Materials

3.1.1 Mammographic unit

The study was performed in one clinic, located in Khartoum, Sudan. Table one shows the characteristic of the equipment mammography unit.

Table 3.1 the machine descriptions in full field digital mammography

Machine	Target/filter combination	Range of kv	Range of mAS	HVL	Serial number	manufacture	installation	hospital
Neusoft	Ag/Rh	20-40kv	5-450	0.298	SN:NM-GA-1506003	Philips	2015	Omer sawey

3.1.2 Quality control phantom

-polymethylmetharcylate (PMMA) commonly called Perspex to mimic different thickness of female breast with different thickness 20, 40,60 and 70 mm (with serial NO. 000328).

-star or bar resolution pattern.

Other material:

- Aluminum sheet with thickness 0.2 mm.

-A4 papers.

- CD.

- Laptop.

3.2 Method:

3.2.1 Place of study:

The study will be conducted in the main hospital in Khartoum state radiology diagnostic department radiation and omer sawey.

3.2.2 Duration of study:

6 month.

3.2.3Quality control perform procedures

Image quality of full field digital mammography was performed by objective criteria. The objective test based on European protocol for the quality control of the physical and technical aspects of mammography screening for digital mammography which was performed The tests by image acquisition are based on the expertise of the different European groups in digital mammography, the American college of radiology imaging Network Dmist trails (ACRIN Dmist) QC protocol , manufacturers QC test and the publication from American Association of physicists in medicine (AAPM) Task Group 10 Concerning CR systems. The test in the image presentation is based on the testing methods and test images of AAPM Task Group18.

.this include conformation to DICOM standard for presentations. The tests were performed by test object thickness 45mm, material objects of PMMA, and other parameters as used clinically.

Mean pixel values and their standard deviation are measured in the standard region of interest, which has an area of 4 cm2 and is positioned 60 mm from the chest wall side and laterally centered.

For spatial resolution test perform based on quality assurance program for digital mammography (international, 2011).

The spatial resolution test was performed by imaging PMMA 3.5mm with exposure parameters 29 kv and 37.9mAs. And contrast –to –noise ratio measured by acquiring several image with several thickness PMMA 20, 40, 60, 70 covering the whole detector area with contrast object (aluminum sheet with thickness 0.2mm) positioned on top, 6cm from the chest wall side.

Table 3.2 : contrast test data

PMMA thickness mm	**Kv**	**mAs**	**MGD**
20	**26**	**21.9**	**0.42**
40	**29**	**35**	**0.70**
60	**31**	**63.8**	**1.23**
70	**32**	**66.8**	**1.33**

3.2.4 Image quality evaluation

Contrast to noise ratio was evaluated by analysis performed using image j software. two regions of interest (ROIs) for each image with different thickness were measured ,one on the contrast object, the second on the background, two parameters mean pixel value and standard deviation were used to calculated contrast to noise ratio.

By formula:CNR= $MPV_{object} - MPV_{background}$ /sqrt[($SD^2_{object} + SD^2_{background}$)]

And spatial resolution evaluated by lp/mm.

MPV_{object} : is mean pixel value for contrast object.

$MPV_{background}$: is mean pixel value for background.

SD_{object} : is the standard deviation of contrast object.

$SD_{background}$-:is the standard deviation of-background.

Spatial resolution was evaluated by lp/mm.

Chapter Four

Results

Chapter Four

Results

4. The Results

Image quality was evaluated for four images in one full field digital mammography. And was evaluated based on the European protocol for the quality control of the physical and technical aspects of mammography screening edition two, the result of CNR was presented in table 4.

Table 4:

Thickness of PMMA	**CNR results**	**acceptable level**
20	**213**	**> 115**
40	**211**	**> 105**
60	**200**	**> 95**
70	**184.8**	**> 90**

Table 5: result of spatial resolution

Thickness	Result/lp/mm	Acceptable limit
3.5mm	23	>=20

Table 6: result of contrast to no ise ratio in this study and other study.

Study	Phantom			CNR			
			20mm	40mm	45mm	`60mm	70mm
This study	PMMA		213	211	-	200	184.8
Ghana,2018	PMMA		211.26	-	111.12	-	103.84
Brazil,2017	ACR	DR1	2.88(11.4)	-	1.85(6.95)	-	0.22(3.6)
		DR2	6.14(8.95)	-	3.42(8.69)	-	1.86(4.42)

Chapter Five

Discussion, Conclusion and Recommendation

Discussion, Conclusion and Recommendation

5.1 Discussion

As Table five shows the comparison of the contrast to noise ratio value between this study and some published value from other studies.

Study was carried out to evaluate image quality and factors effect on it 5.1: in one hospital. Mean values of contrast to noise ratio for each thickness and spatial resolution in this study as bar pattern is acceptable value according to the European protocol for the quality control of the physical and technical aspects of mammography screening edition two.

When CNR value in this study were compared with those from the literature. The current value of CNR is more acceptable compare from some studies in some countries. Result in this study indicated the neusoft full field digital mammography in omer sawey hospital has good image quality.

Were observed when increase thickness of phantom decreases the contrast to nose ratio.

The values of contras – to - noise ratio in this study (213, 211,200 and184.8 f0r thickness of PMMA 20, 40, 60 and 70mm respectively) is higher than values found in other studies: for example, Sosu. E et al (211.96, 111.12 and 103.84 for thickness of PMMA 20, 45 and 70mm respectively) [8]. In another study. Xavier.A et al carried out based on the IAEA (international…, 2011) CNR value for two DR system for DR1(1.88(11.54) A(A),1.85(6.95) A(A) AND 0.22(3.61)NA(NA) FOR 20, 45, 70mm respectively) for DR2 (6.14(15.07)A(A), 3.42(8.69)A(A)and (1.885(4.42)A(A) FOR 20, 45, 70mm for 20, 45, 79mm respectively), in parenthesis, contrast for aluminum square, where A means adequate and NA means not adequate within the limits proposed by the IAEA(international …, 2011) .

5.2Conclusion:

Image quality of full field digital mammography in omer sawey hospital (neusoft) was evaluated. The PMMA slabs 20,40,60,70mm thickness and aluminum sheet 0.2mm thickness Used to evaluate CNR and PMMA WITH 3.5 thickness and bar pattern were evaluated spatial resolution. We found the whoever CNR and spatial resolution within acceptable value according to European protocol.

5.3 Recommendation

Quality control test must be carried periodically and frequently**.**

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