Technical Advances, Image Quality and Quality Control Regulations in Mammography

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ABSTRACT

Mammography is considered the single most important diagnostic tool in the early detection of breast cancer. Today's dedicated mammographic equipment, specially designed x-ray screen/film combinations, coupled with controlled film processing, produces excellent image quality and can detect very low contrast small lesions. In mammography, it is most important to produce consistent high-contrast, high-resolution images at the lowest radiation dose consistent with high image quality. Some of the major technical development milestones that have let to today's high quality in mammographic imaging are reviewed. Both the American College of Radiology Mammography Accreditation Program and the Mammography Quality Standards Act have significant impact on the improvement of the technical quality of mammographic images in the United States and worldwide. A most recent development in digital mammography has opened up avenues for improving diagnosis.

Keywords: mammography, breast imaging, image quality, quality control, digital mammography

1. INTRODUCTION

Mammography is considered the single most important diagnostic modality in the early detection of breast cancer. Today's dedicated mammographic equipment, specially designed x-ray screen/film combinations, coupled with controlled film processing, can detect very low contrast lesions as small as one-tenth of a millimeter (100 microns), as much as two years before they are palpable. Image quality is better while radiation dose is 50 to 100 times lower compared to early mammographic systems. The widespread application of screening mammography over the last 25 years has decreased the mortality from breast cancers in the US to range from 8% to 25%[1].

Consistent high-contrast, high-resolution images at the lowest radiation dose consistent with high image quality are vital, however serious difficulties present themselves. In recent years, there have been many significant technological improvements in mammographic x-ray equipment, image recording systems, and viewing conditions.

2. TECHNICAL ADVANCES IN MAMMOGRAPHY

There have been significant advances in mammographic x-ray equipment and in screen/film recording systems over the past 25 years[2,3]. Until the mid 1980's, many x-ray units were used that were not dedicated to mammography. These units had tungsten target tubes that were originally designed for other medical imaging procedures, such as chest radiography. Many of these units had home made compression devices that could not assure adequate compression of the breast. Many of these units had very large focal spots or short focal spot-to-breast surface distances that could result in significant geometric blur (unsharpness). Direct exposure (industrial type) x-ray films were being used, which often required long exposure times (causing blur by motion) and which resulted in high radiation exposure. In addition, viewing conditions were inadequate.

Today, mammography is performed with dedicated mammography x-ray equipment[2,3]. These units have specially designed x-ray tubes, smaller focal spots, and significantly improved breast compression devices, among other features. Modern x-ray tubes have multiple targets of tungsten, molybdenum and rhodium that are selected by microprocessor to give optimum tissue penetration. Cassettes and special films and intensifying screens are designed especially for mammography. Film processing has been the major weakest link giving rise to image quality problems and artifacts.

Nevertheless this has also improved significantly over the years. Today it is possible to obtain mammograms with higher image quality at a significantly lower radiation dose compared to 25 years ago. In 2000, the first digital mammography system was approved by the Food and Drug Administration (FDA) for clinical use.

Historical milestones in technical advances in mammography[2,3,4]

Year	Development	
<1969	Conventional tungsten target x-ray tubes with direct exposure industrial type film	
1969	Dedicated mammographic unit with molybdenum target tube & compression device	CGR Senographe
1971	Xeromammography	Xerox
1972	Screen-film system	Du Pont Lo-dose system
1976	Rare earth screen-film system and special cassette	Kodak Min-R system
1977	Magnification with microfocal spot	Radiological Sciences Inc.
1978	Grid	Philips
1987	American College of Radiology Mammography Accreditation Program	ACR
1992	American College of Radiology Mammography Quality Control Manual introduced	ACR
1994	Mammography Quality Standards Act (MQSA) implementation	FDA
2000	1st Digital Mammography approved by FDA for clinical use	GE Senographe 2000D

3. IMAGE QUALITY

Obtaining optimum image quality in mammography is technical demanding especially it impacts on the accuracy of diagnosis. Fig 1 shows measured x-ray attenuation coefficients of fibroglandular breast tissue, fat, and breast carcinoma versus x-ray energy[5]. The small difference between the curves illustrate why mammography is such a challenging imaging task, particularly when the tumour is surrounded by fibroglandular tissue. The limited dynamic range of film-screen mammography presents a serious limitation in detecting and recording the various components of the breast. The sigmoidal characteristic curve (Fig. 2) is such that the contrast is high for intermediate exposure areas but low for low as well as high exposures. In other words, 'thin' and 'dense' areas of the breast are displayed with low contrast; but this is improved with digital mammography.

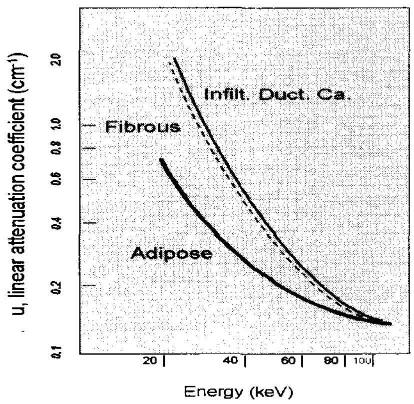

Fig 1. Attenuation coefficients of various Breast tissues[5].

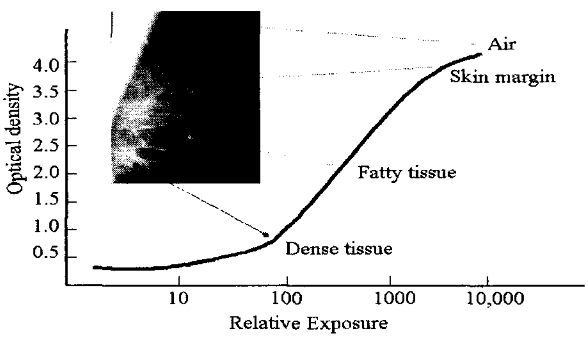

Fig. 2 Mammography characteristic curve showing limited dynamic range

4. QUALITY CONTROL REGULATIONS

Since the American Cancer Society guidelines for early detection of breast cancer have become widely accepted in the medical community, and because some facilities were known to produce poor quality mammograms, in 1987 the American College of Radiology (ACR) developed the Mammography Accreditation Program which placed a strong emphasis on controlling and maintaining image quality and radiation dose levels. The ACR Quality control Manuals was introduced in 1992[6]. Test procedures recommended for the medical physicist are: Mammography unit assembly evaluation, collimation and alignment assessment, evaluation of system resolution, AEC system performance assessment, uniformity of cassette/screen response, artifact evaluation, image quality evaluation, generator performance, beam quality assessment, mean glandular dose, radiation output rate, viewbox luminance and room illuminance, compression, leakage radiation, primary protective shielding assessment. The ACR recommended mean glandular dose per film for an examination of 4.5 cm-thick compressed breast of average composition to be less than 1 mGy (without grid) and 3 mGy (with grid) respectively. Image quality analysis is performed to ensure that the film optical density, contrast, uniformity, and image quality imaging system and film processor are maintained at optimum levels. This is accomplished using an accreditation phantom (RMI 156 or 18-220) that simulates fibers, specks (micro-calcifications) and masses. Viewbox luminance and room illuminance also receive greater attention recently.

In October of 1994, the Mammography Quality Standards Act (MQSA) became law[7]. Under MQSA, a mammography facility must be certified by the Food and Drug Administration (FDA). MQSA requires annual medical physicist surveys on screen-film mammogram equipment. QC tests that fail require corrective action within a specified timeframe. Additional testing is required when equipment is replaced or repaired. This has a significant impact on the improvement of the technical quality of mammographic images in the United States and worldwide.

The ACR Mammography Accreditation Program developed guidelines that have become the international standard for quality control programs. Accreditation by the ACR requires:

1. a completed questionnaire about the credentials of staff, type of x-ray equipment, image receptors, processing, and quality control procedures used;
2. submitting mammograms for evaluation by a panel of radiologists;
3. submitting a breast phantom image for evaluation by a panel of medical physicists;
4. radiation dose evaluation; and
5. submitting film processor control data.

The National Council on Radiation Protection and Measurements (NCRP) has prepared a new report "Mammography 2002" replacing the NCRP Report No. 85, "Mammography - A User's Guide", 1986[8]. Its recommendations regarding equipment specifications and quality control activities are consistent with those in the MQSA. The final MQSA regulations require that before a medical physicist may provide professional services on a new mammographic modality (such as Full Field Digital Mammography -FFDM) independently, the physicist must receive at least 8 hours of training in surveying units of the new mammographic modality. Also facilities using the FFDM system(s) must perform quality control (QC) tests as required by the FFDM manufacturers.

5. DIGITAL MAMMOGRAPHY

Digital mammography is the only *last* major digital imaging technique recently available. Digital mammography uses essentially the same mammography system as conventional mammography, but the system is equipped with a digital receptor to capture the breast image digitally for display on a computer monitor. With digital mammography, the magnification, orientation, brightness, and contrast of the image may be altered after the exam is completed to help the radiologist more clearly see certain areas. It presents a unique opportunity and challenge for us to deal with a new set of technical considerations, understand the physical principles and the quality control. This technique offers many benefits: improved contrast resolution, reduced radiation dose, post-acquisition image enhancement, rapid image display, improved imaging in dense breasts, improved sensitivity and specificity, simplified archival, retrieval and transmission, potential for computer-aided diagnosis and telemammography.

The x-ray detector system is fundamental to the performance of digital mammography. Currently these detector technologies are utilized: flat panel imagers using amorphous silicon detector arrays integrated with a scintillator, flat panel direct detection approaches using amorphous selenium, photostimulable phosphors, and slot scanning techniques using charge-coupled devices.

Status of development in full-field digital mammography (FFDM)

Status (as of Aug 02)	FFDM	Detector type
FDA approved	GE Senographe 2000D	Amorphous silicon
	Fisher SenoScan	Charge-coupled device
	Hologic Lorad Digital Breast Imaging	Charge-coupled device
Under clinical investigation	Siemens/Fuji FCR	Photostimulable phosphor
	Sectra MicroDose Mammography	Amorphous silicon
	Hologic/Agfa Selenia	Amorphous selenium
	Instrumentararium Diamond	Amorphous selenium

While digital mammography is quite promising, it still has some limitations before it can replace conventional mammography. Digital mammography must provide higher detail resolution (standard film-screen mammography provides up to 20 lp/mm) and become less expensive (digital mammography is currently 4 to 5 times more costly than conventional mammography).

The accuracy of the current digital mammography systems versus screen-film mammography is being evaluated in the Digital Mammographic Screening Trial (DMIST) study on 49,500 women, conducted through the ACR Imaging Network (ACRIN)[9] at 19 study sites in the US and Canada. This largest U.S. federally funded clinical trial on medical imaging study is in progress now. The full impact of digital mammography is likely to become significant when novel and emerging applications such as computer-aided detection (CAD), telemammography, contrast uptake imaging, tomosynthesis, tissue characterization, and risk prediction through breast density analysis.

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