[Frontiers in Bioscience 1, b5-7, 1 August, 1996]

COMPARISON OF CONTRAST DETAIL CURVES OF FULL FIELD DIGITAL WITH SCREEN FILM BREAST PHANTOM IMAGES

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ABSTRACT

In this investigation, we imaged a standard breast phantom and compared the contrast detail curves from a prototype full breast digital mammography system with the corresponding curves for a conventional, analog screen-film system. The full breast digital system exhibited superior contrast detail detectability. The results from this study will be used to plan future clinical evaluations comparing full breast digital and screen film mammography.

INTRODUCTION

Breast cancer is the most common cancer of American women and is the leading cause of cancer related death among women aged 35-50 years old in the United States (1). It is estimated that in 1996, 185,700 women will be diagnosed with breast cancer and that 44,560 women will die from this disease (2). Early detection of breast cancer results in a high probability of cure (3-5). Currently, virtually all mammographies are performed using screen-film systems and dedicated mammographic x-ray units. However, because of several inherent limitations of film as a recording device for the mammographic image, conventional screen-film mammography is limited in its ability to detect cancers in patients with radiodense breast tissue (6-8). These women, including premenopausal women or those undergoing hormone replacement therapy, comprise approximately 40% of the general population (9). Through increased sensitivity, wider dynamic range, lower noise, and improved contrast resolution, x-ray sensors that acquire the mammographic image in direct digital format provide a means of overcoming many of the drawbacks of screen-film mammography.

We have recently begun to evaluate a prototype full breast digital mammography unit (LORAD/ Thermotrex, San Diego, CA). The x-ray source is equipped with a tungsten target and a 50 µm silver filter. The digital detector utilizes two 1k x 1k charge-coupled devices (CCDs) which are optically coupled with cesium iodide (CsI) scintillators by two large aperture and finite conjugate Schmidt lenses (Figure 1). Twelve sub-images are acquired by shifting the CCD cameras to six positions. Each sub-image covers a field of 6cm x 6cm (64 µm pixel size). A computer stitching algorithm combines the sub-images into a single 24cm x 18cm mammographic image. The final image is a 4K x 3K x 12 bit digital array. The objective of this technical evaluation was to compare the contrast detail curves of mam-mographic phantom images obtained using the full breast digital mammographic system with a conventional screen film mammographic system at equivalent, clinically relevant radiation doses.

METHODS

The CDMAM Phantom Type 3.2 (Nuclear Associates, Carle Place, NY), specifically designed to evaluate mammographic systems, consists of an aluminum base with gold disks of various thicknesses (depth) and diameters, attached to a plexiglass cover (10). The diameter of the phantom objects (gold disks) ranges from 3.2 to 0.10 mm and the thickness of the objects ranges from 0.05 to 1.60 µm. The disks are arranged in a matrix of squares comprising 16 rows and 16 columns. Within each row, the diameter of the gold disk is constant with logarithmically increasing thickness. Within each column, the thickness of the gold disk is constant and its diameter increases logarithmically. In each square, there are two identical disks, one in the center and the other at a randomly chosen corner. For the imaging experiments, the phantom was positioned on each system with the smallest disk diameters at the chest wall side of the mammographic device. Four plexiglass plates were placed on top of the CDMAM phantom to simulate a 5 cm thick breast. The phantom and plexiglass plates were imaged at equivalent radiation doses on both the full breast digital and the screen film mammographic systems. Screen film breast phantom images were obtained at 25 kVp and 194 mRad mean glandular dose (Figure 2a); digital breast phantom images were obtained at 33 kVp and 194 mRad (Figure 2b). Using the method devised by the CDMAM phantom developer (11), the resultant images were evaluated to determine the threshold contrast (the minimal perceptible disk thickness) detectable for each diameter. For each square in the analog and digital images, a single observer identified the location of the eccentric disk. At least three squares were observed in each column and each row. The indicated positions for the eccentric disks were then compared to the true locations. For each row, where the diameter of the disks is constant, the thinnest disk correctly localized is taken as the minimal detectable thickness for the given diameter.

Received: 5/15/96; Accepted: 7/8/96

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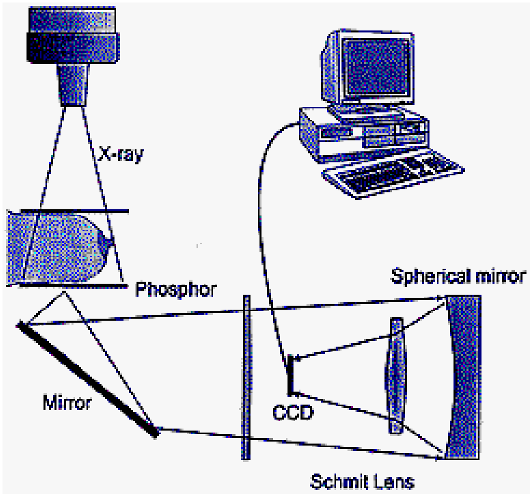

Fig. 1. Schematic of a CsI-Lens-CCD imaging module. The LORAD full breast digital mammography system utilizes two such modules.

Fig. 2 (a) Analog screen-film CDMAM phantom image. This image was obtained at 25 kVp and 194 mRad mean glandular dose, using a clinical screen-film mammography system, (Model: M-III, LORAD Corporation, Danbury, CT)

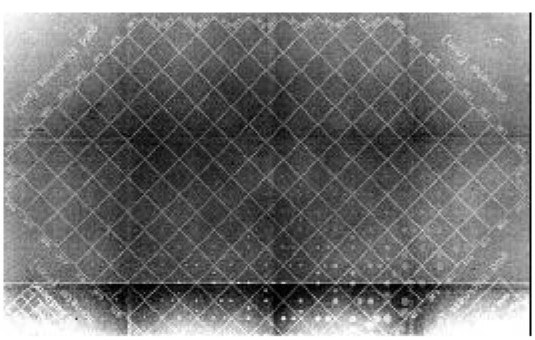

Fig. 2 (b) Digital CDMAM phantom image. This image was obtained at 33 kVp and 194 mRad using the prototype full breast digital mammography unit (LORAD/Thermotrex, San Diego, CA).

RESULTS & CONCLUSIONS

For both the analog and digital images, curves relating the detail diameters and the minimal detectable disk thickness are shown in Figure 3. The resulting curves demonstrate that the prototype digital mammography system imaged smaller and lower contrast phantom objects than the screen-film system. For example, at an object diameter of 3.2mm, the minimum thickness at which the object was detectable by the digital system was 0.08µm. At the same diameter, the object was not detected by the screen-film system until the thickness reached 0.10µm. At a diameter of 0.5mm, the minimal detectable thickness was 0.25µm for the digital system and 0.31µm for the screen-film system. For an object diameter of 0.16mm, the minimal detectable thickness for the digital system was 1.0µm and for the screen-film system it was 1.6µm.

The prototype unit investigated in this study is one of the first full breast digital mammography systems undergoing clinical evaluation. The results of our preliminary technical evaluation show superior detectability using the digital mammography system, inspite of its lower spatial resolution (about 7 cycles per millimeter) compared with the screen-film system (about 16 cycles per millimeter). Early results from other development programs for digital mammographic detectors have also verified that spatial resolution is only one of several factors which determine the ability of an imaging system to resolve small objects (12). Thus, the superior contrast resolution and potentially lower noise characteristics of a well-designed digital breast imaging system may compensate for a lesser spatial resolution.

Many innovative approaches to full breast digital imaging are being pursued currently. Implementation of such systems will result in mammograms of higher quality than those presently available. The advantages of better image quality, real time display, ease of image management and access to digitally based image manipulation and transfer technologies may ultimately enable full breast digital mammography to replace screen-film mammography.

In light of the magnitude of the breast cancer problem and the improvement in prognosis associated with efficient, early detection, digital mammography may become the standard modality in the near future.

ACKNOWLEDGMENTS

This work was supported in part by the Whitaker Foundation (Biomedical Engineering Research Grant), and by a NIH grant CA69043 (to H Liu).

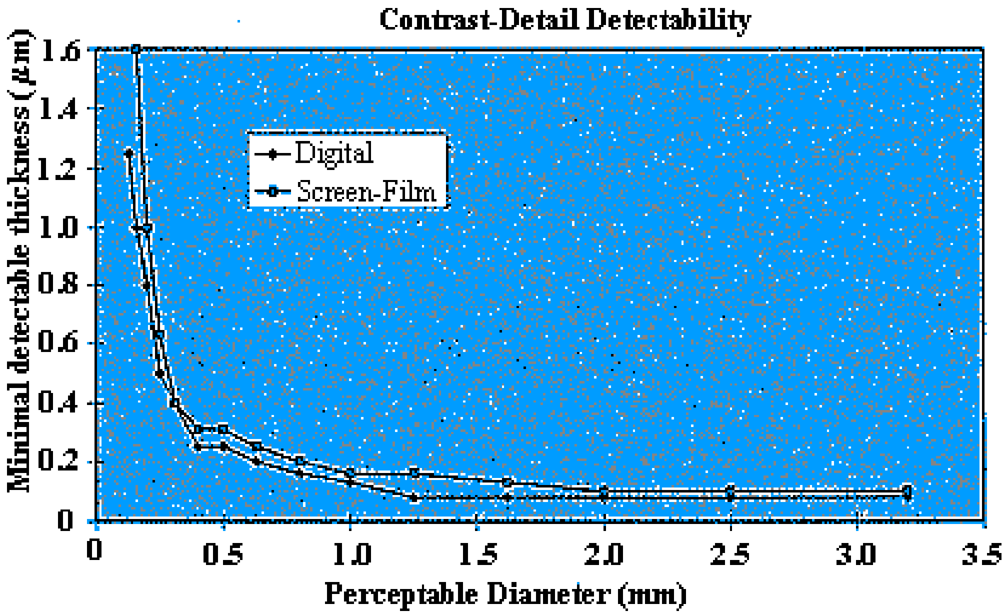

Fig. 3. The contrast-detail curves of both the digital and the screen-film systems. Both the digital image and the analog screen-film images were acquired at 194 mRad mean glandular dose.

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