Contrast Threshold of 4 Full Field Digital Mammography Systems Using Different Measurement Methods

A.-K. Carton[1], H. Bosmans[1], C. Vanongeval[1], G. Souverijns[2], G. Marchal[1], J. Jacobs[1], D. Vandenbroucke[3], H. Pauwels[1], and K. Nijs[1]

[1] Radiology, University Hospital Gasthuisberg, B-Leuven
[2] Virga-Jesse, B-Hasselt
[3] Agfa, B-Mortsel

Abstract. We compared three conspicuity tests applied to four full field digital mammography (FFDM) systems. The tests included: 1) the calculation of noise equivalent quanta (NEQ); 2) contrast-detail analysis with the CDMAM 3.4 phantom and 3) evaluation of the detectability of (simulated) microcalcifications with specific well-known dimensions in mastectomy images. For each contrast-resolution test method, the exposure, processing and viewing conditions were identical. As a result, the only variable for a given test was the physical performance of the detector. The three test methods each rank the detectors in the same order. The flat-panel detector ranked the best overall, the dual-sided read-out storage phosphor detector ranked second and the single-sided-read-out storage phosphor detectors with 50 µm and 100 µm pixel sizes ranked similarly and were inferior to the other 2 detectors.

1 Purpose

Digital mammographic detectors need both high spatial resolution and excellent contrast. These characteristics can be measured in several, very different, ways and ultimately determine the contrast threshold visibility for various object sizes. In the present study, we have applied three test methods that assess efficacy in different ways: 1) the calculation of noise equivalent quanta (NEQ) [1]; 2) a contrast threshold detectability study using a contrast-detail phantom [2]; and 3) a detectability study of (simulated) microcalcifications on a mammographic background [3,4]. The first and second methods are generally accepted tests used by medical physicists.

2 Material and Methods

The four detectors encompassed an amorphous-selenium based detector (the Embrace DM1000 of Agfa, (acronym: DM1000)) and three storage phosphor detectors (the FCR 5000MA of Fuji (acronym: FCR), the Embrace CR of Agfa with pixel size 100µm (acronym: Emb100) and a non-commercially available CR detector of Agfa with pixel size 50µm (acronym: Emb50)). The FCR has the unique feature of a double-sided readout of the plates with a pixel size of 50µm. The Emb100 and the Emb50 make use of the same storage phosphor plates by Agfa. They were read-out

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with the same single-sided reader but with a pixel size of 100µm (Emb100) and 50µm (Emb50). The FCR, Emb50 and Emb100 images were acquired with a M-IV Platinum mammography unit (Lorad, Danburry, CT). The DM1000 detector is integrated in a mammography x-ray system of identical make and model using a similar x-ray generator, anode and filter combinations. The only difference of this system is the linear moving grid, whereas the M-IV Platinum mammography unit (used for the CR plates) has a cellular grid.

2.1 NEQ

The horizontal and vertical NEQs [1] were derived from the measured pre-sampled modulation transfer functions (MTF) [5] and normalized noise power spectra (NNPS) [6] as follows:

$$\mathrm{NEQ}(\omega) = \frac{\mathrm{MTF}^2(\omega)}{\mathrm{NNPS}(\omega)}$$

where ω is the spatial frequency. The MTFs were calculated from images of a 5cm by 5cm, 30µm thick Pb-edge laminated between two 20mm thick PMMA slabs. The NNPS were computed from images of a 40mm thick homogeneous PMMA slab. The exposures were made at 28 kVp (nominal) and Mo/Mo. We used 64mAs for the FCR, Emb50 and Emb100 and 55mAs for the DM1000. The computations were performed in the raw data; i.e. linear with exposure. Errors on the NEQs were computed from the propagation of the absolute errors calculated for the MTF and NNPS.

2.2 Contrast-Resolution from CDMAM 3.4

The CDMAM 3.4 [2] sandwiched between two 20mm thick PMMA slabs was exposed at 26 kVp, Mo/Mo and 160mAs for the FCR, Emb50 and Emb100 and 129mAs for the DM1000. Repeated exposures were acquired with each detector. The raw image data were square-root compressed. The window width and level were optimized and set identical for all images. The images were printed with a high resolution (508 ppi – 8 bits) Mammoray 4500 Drystar printer (Agfa, Mortsel, Belgium). All images were viewed by 7 experienced medical physicists in a darkened room on the same view box. The use of a magnifying glass was encouraged and a minimum viewing time of 15' was imposed. Contrast-detail curves averaged over all 7 observers and 2 images per detector were plotted for the four detectors. The fractional standard deviation SE_t on the average threshold contrast was calculated using the equation given by Swets and Pickett [7]:

$$SE_t = \left(\frac{S_c^2}{n} + \frac{S_b^2}{l} + \frac{S_w^2}{nml} \right)^{1/2}$$

In this equation S_c^2 is the fractional case sample variance, S_b^2 is the fractional between-observer variance and S_w^2 is the fractional within-observer variance. The number of replica images for each detector is n, the number of observers is l and the