Validation of a Simulated Dose Reduction Methodology Using Digital Mammography CDMAM Images and Mastectomy Images

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\textbf{Abstract.} The purpose of this study is to evaluate the effect of simulated dose reduction using CDMAM and mastectomy images acquired on two digital mammography systems. High dose images have been artificially degraded to reduced dose levels by systematically adding filtered noise. Automated scoring has been carried out on the degraded CDMAM images and on experimental CDMAM images, taken at the same corresponding reduced doses. Contrast-detail curves were derived for both, at all doses, and compared. Relative difference in the contrast-detail curves was approximately 5\% overall for all four doses.

For the mastectomy images noise power spectra were obtained and the ratio of experimental to synthetic low dose NPS profiles averaged for all doses at 1.04. The largest differences in the NPS profiles were found at the high spatial frequencies, corresponding with the differences in the small discs in the contrast-detail curves.

\textbf{Keywords:} Digital mammography, simulation, CDMAM phantom, validation, mastectomy, dose reduction.

\section{1 Introduction}

There is a growing interest in image simulation in digital radiography, and in mammography in particular\cite{2,3,4,5,6}. Image simulation provides a means to optimise digital mammography systems for improved breast cancer detection. Image simulation studies could make clinical trials more targeted as simulation studies can be used to study some effects in advance.

Recently, there has been focus on the effect of reducing dose levels in digital mammography images upon detection of mammographic lesions\cite{12}. Results
indicate that dose could be reduced with little detriment to the detection of masses. However, the task of microcalcification detection appeared to have significantly greater dependence on the increased relative noise in the images. This is because breast structure noise dominates when trying to detect relatively large objects such as masses but detector noise is important for the detection of small details such as microcalcifications. In contrast-detail tasks such as scoring of images of the CDMAM phantom, there is a direct link between increasing dose and the detection of small details\cite{7}. This study aimed to validate a method to simulate reduced radiation dose in digital mammograms. The same methodology is applied to mastectomy images for further analysis with use of spectral analysis\cite{8,9}.

2 Methodology

2.1 Materials

Sixteen images of the CDMAM (version 3.4) were acquired at each of five doses using the Hologic Selenia system with the CDMAM phantom placed between two slabs of PMMA 2cm thick. The images acquired at the highest dose (31kVp Mo/Rh, 5.91mGy mean glandular dose) were used as the reference images for the subsequent synthesised low dose images (0.34, 0.80, 1.48, 2.95mGy MGD). Flat field images for 5cm of PMMA were acquired at the same beam quality, exposure settings and setup as the CDMAM images. Detector response and NPS measurements were carried out on these flat field images and used for the dose reduction methodology.

Four sets of mastectomy images were acquired on the Siemens Novation system. Each mastectomy sample was placed on the breast support and compressed. The mastectomy sample was exposed with the tube voltage held constant whilst the tube current time product was varied. Care was taken not to move the mastectomy sample after each exposure. The highest dose mastectomy image was used as the reference image for synthesizing subsequent lowered dose images. Table 1 shows the doses used for each mastectomy set as well as their compressed thicknesses. Flat field images using three and five centimetres of PMMA was used in the same setup as the mastectomy samples for detector response and NPS measurements to be used with the dose reduction methodology. Note that all images used in this study are raw and unprocessed.

2.2 Dose Reduction

Båth et al’s methodology\cite{10}, which had been previously applied to chest X-ray images, has now been implemented for the first time to degrade the following experimentally acquired mammography images: CDMAM and mastectomy images. Furthermore, the NPS was modelled to three noise sources: electronic, quantum and structural. Firstly, the linearised pixel intensity values of the original image, $I_o(x, y)$, were scaled by a ratio of the dose to be simulated, $D_{sim}$, to the original