Dual Energy Tomosynthesis breast phantom imaging

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Abstract. Dual energy (DE) imaging technique has been applied to many theoretical and experimental studies. The aim of the current study is to evaluate dual energy in breast tomosynthesis using commercial tomosynthesis system in terms of its potential to better visualize microcalcifications (μCs). The system uses a tungsten target X-ray tube and a selenium direct conversion detector. Low-energy (LE) images were acquired at different tube voltages (28, 30, 32 kV), while high-energy images at 49 kV. Fifteen projections, for the low- and high-energy respectively, were acquired without grid while tube scanned continuously. Log-subtraction algorithm was used in order to obtain the DE images with the weighting factor, w, derived empirically. The subtraction was applied to each pair of LE and HE slices after reconstruction. The TORMAM phantom was imaged with the different settings. Four regions-of-interest including μCs were identified in the inhomogeneous part of the phantom. The μCs in DE images were more clearly visible compared to the low-energy images. Initial results showed that DE tomosynthesis imaging is a promising modality, however more work is required.

1. Introduction

X-ray mammography is currently the best method to search for alterations that might indicate cancer [1]. Mammography has been demonstrated to reduce breast cancer mortality [2], however it has low positive predictive value and sensitivity [3, 4] due to anatomical noise resulting from superimposition of normal structures. Magnetic resonance imaging (MRI) may be used for screening purposes in patients with dense breasts. However, the long examination time along with the expensive equipment, makes MRI screening extremely costly compared with screening mammography and digital breast tomosynthesis (DBT) [5].

DBT is of great interest in screening and diagnostic breast imaging. The ability to provide “slices” through the breast and reduce the noise of the tissue structures is the major advantage of tomosynthesis. Due to this benefit, DBT has been shown to improve detection of abnormalities in women with dense breast tissue, reduce recall rates and improve diagnosis of benign lesions (reduced number of negative biopsies) [6].

Dual energy (DE) imaging technique can improve the conspicuity of a suspicious tissue. DE imaging suppresses the signal of one tissue material resulting in removal of anatomic background
noise [7,8]. Thus, the contrast of the feature of interest is enhanced [1].

Microcalcifications (μCs) are calcium deposits in the soft tissue of the breast that can indicate the presence of cancer and appear as a spot or as group, called “clusters of microcalcifications” [1]. The detection of clustered μCs is an important component of mammographic analysis. Since tomosynthesis presents “slices” of the breast, the observer may not perceive the microcalcifications that are not encompassed in a single slice [9].

The purpose of this study was to investigate the potential to better visualize microcalcifications using dual energy in digital tomosynthesis. A commercial tomosynthesis system with tungsten target X-ray tube and selenium direct conversion detector was used. Log-subtraction algorithm was applied to each pair of low-energy (LE) and high-energy (HE) slices after reconstruction. Four regions-of-interest (ROIs) including μCs were identified in the inhomogeneous part of the TORMAM phantom. The μCs in DE images were more clearly visible compared to the LE images.

2. Materials and methods

This work is based on the images obtained with the 3D Hologic Selenia Dimensions system (Hologic Inc., Bedford, USA). The system has a tungsten anode X-ray tube and three filter options in the commercial release. The X-ray generator has a maximum tube current of 200 mA and a voltage range from 20 up to 49 kV. It has various automatic exposure control (AEC) modes. For the acquisition of the DBT images, the high transmission cellular anti-scatter grid was automatically removed out of the X-ray field. The screening mode was selected and 15 projections acquired over 15 degrees (-7.5° - +7.5°) scan angle in 3.7 seconds. The tube was scanned continuously, allowing fast scan time. Reconstruction is performed using a filtered back projection algorithm (FBP) obtaining contiguous planes with thickness of 1 mm. DBT images are acquired using the 0.7 mm thick aluminum (Al) filter. For the LE images three kVs were used: 28, 30 and 32 kV. Also, the auto-time AEC mode was used, at which the user selects the filter and the tube voltage, while the system selects the mAs. The HE kV was set to 49 kV, since it was the highest that could be used, but further optimization of the HE kV is to be done in follow-up study. For the HE, the manual AEC mode was used, at which the user selects all the parameters (kV, filter, mAs). The dose allocation between the LE and HE exposures was selected to be 0.5 in this study. For the calculation of the corresponding mAs that should be used for the HE exposure, in order to result in equal entrance dose to that of LE exposure, the Barracuda dosimeter (RTI Electronics) coupled to an ionization chamber (Magna A600) was positioned at the surface of the TORMAM phantom and the entrance dose was measured for each LE exposure.

Images of the TORMAM phantom (Leeds Test Object Ltd, Boroughbridge, UK) were obtained. The middle right of the phantom test plate simulates the appearance of breast tissue; it contains calcification clusters with sizes of 354-224, 283-180, 226-150, 177-106, 141-90, 106-93 µm, in addition to fibrous material and nodules. The exact location of the features in the structured background is unknown. The middle left with uniform background contains 18 low contrast objects, filaments and the calcification clusters as shown above. The test plate (1.6 cm) was positioned on the center of the polymethyl methacrylate (PMMA) slabs of 4 cm thickness, resulting in a total thickness of 5.6 cm.

The DE images were obtained by weighted log pixel-by-pixel subtraction method [8]. The LE and HE projection images were firstly reconstructed into LE and HE volume slices separately, and then weighted logarithmic subtraction was performed with each pair of LE and HE images of the same height, as defined in Eq. 1:

\[ \text{DE} = \ln(\text{HE}) - w \ln(\text{LE}) \tag{1} \]

where HE and LE refer to pixel intensity of high- and low-energy reconstructed images, respectively and w is the weighting factor.

Four ROIs containing calcification clusters were identified in LE and HE reconstructed images of the realistic breast tissue part of the phantom. For each ROI of LE and HE images, a number of DE
images were generated for all weighting factors in the range of 0 to 1, at 0.01 intervals. The standard deviation (σ) in the DE-DBT images was computed for two background regions (without calcifications present) using a custom-developed algorithm. The optimal locally adjusted \( w \) [10] was defined as that which minimizes \( \sigma \).

3. Results and discussion
Figures 1, 2 and 3 illustrate the inhomogeneous part of the TORMAM phantom acquired at 28, 30 and 32 kV, respectively. Four ROIs with size of 50x50 pixels were selected in each LE image, containing \( \mu \)Cs. The corresponding ROIs of the DE images, as defined in LE images, are also shown at the right side of the figures.

**Figure 1.** LE image of TORMAM phantom at 28 kV and the corresponding ROIs of the DE image.

**Figure 2.** LE image of TORMAM phantom at 30 kV and the corresponding ROIs of the DE image.

**Figure 3.** LE image of TORMAM phantom at 32 kV and the corresponding ROIs of the DE image.
The tomosynthesis slice was selected at the height of the test plate location. While the μCs were obscured by the surrounding tissue in LE images, in DE subtraction images the background tissue structures were well suppressed. Thus, μCs are highlighted and are more clearly visible in the DE images.

The w factor was locally adjusted in this study and ranged from 0.36 to 0.53 for all examined ROIs. It has been shown that w factor varies with the breast tissue composition [11]. If a single value is selected, then the suppression of the background structure may be lower. Furthermore, w is affected by the beam quality and the average beam energy [11].

4. Conclusions
The aim of the present work was to evaluate the potential of dual energy in breast tomosynthesis in order to better visualize μCs. The LE images were acquired at different tube voltages, while HE images at 49 kV. In DE images the four μCs clusters were better defined than in the corresponding LE images. The initial results showed that DE tomosynthesis imaging could be a promising modality, however more work is required.

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5. References
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